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The Relative Position of Rest of the Eyes and the Prolonged Occlusion Test

BY

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*ILLUSTRATED WITH
ORIGINAL DIAGRAMS AND CHARTS*



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PREFACE

THE methods of examination of the ocular muscles, their functions and anomalies, have been brought to such a high degree of perfection by the work of Von Graefe, Landolt, Stevens, Duane, Maddox, Howe and others, that it is with much hesitation and some sense of presumption that this incursion into the field is made.

The modification in the method of using the screen test with which this essay deals has, however, yielded the writer such valuable aid in the elucidation of many otherwise—to him—very obscure problems, that he feels justified in publishing in a fuller form than an ordinary paper to be read at some society meeting would permit, an account of the method, the observations that have been made with it, and the inferences which it seems should be drawn from them.

The fact that many ophthalmologists have met with so many disappointments in their attempts to deal with these conditions that they have ceased to pay attention to them, is in itself evidence that the methods ordinarily used for diagnosis fail to reveal the truth, and that treatment has consequently been based on insufficient and often on misleading data.

The writer wishes to acknowledge the invaluable assistance received from his son, Dr. S. B. Marlow, in the work of tabulating and classifying the cases.

F. W. M.

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CHAPTER I.

INTRODUCTORY.

OF the two strictly ocular groups of causes of asthenopia, the ametropias and the heterophorias, the former presents a field the thorough exploration of which has been made possible by a number of subjective and objective methods, the efficiency of which has been materially raised by the use of cycloplegia, thus eliminating the action of the accommodation and permitting the static refraction to be measured with a high degree of accuracy. This somewhat trite statement is made only for the purpose of comparison of the refractive with the muscle balance problem.

In hypermetropia and to some extent in astigmatism we have anomalies the effect of which is offset by an exact adjustment of accommodation to maintain *clear* vision, and this accommodative adjustment has to be maintained so constantly that the ciliary muscle gets into a state of chronic contraction—accommodative spasm—and does not completely relax when its action is made unnecessary by glasses, for a length of time varying in different cases, *unless a cycloplegic is used.*

In the heterophorias we have anomalies the effect of which is offset by an exact adjustment of the extrinsic muscles to maintain *single* vision, and that adjustment has to be maintained so constantly that the extrinsic muscles get into a state of chronic contraction—muscular spasm—and when their action is made unnecessary by the annulment of binocular vision they do not completely relax, for a length of time varying in different cases, *unless some*

drug analogous to a cycloplegic be found to relax the spasm.

It is unnecessary to say that no such drug has yet been found, and consequently the investigation of the muscle balance lacks the completeness and precision which characterize that of the refraction. To accomplish a relaxation of the extrinsic muscles, which have become contracted in response to the habitual demands of the binocular function, we have, therefore, to fall back upon an annulment of that function, maintained for a length of time sufficient for the purpose. Hitherto, what length of time is sufficient to effect a relaxation has been left out of consideration.

The object of this monograph is to indicate the effect of prolonging the cover test sufficiently to allow the desired relaxation. The term "Prolonged Occlusion" seems sufficiently descriptive of this test.

"When some member of the A. M. A. has discovered and made practical the use of a myoplegic that will paralyze the extraocular muscles, as a mydriatic does the intraocular muscles, we shall have made giant strides towards solving the physiology of the extraocular muscles.

"It would probably upset some of our pet notions of today and require us to set up new standards." (Reber: Jour. A. M. A., Jan., 1901.)

Although the prolonged occlusion test for heterophoria, and the cycloplegic test for ametropia are not exactly analogous, the difference between them is not so great as at first thought appears to be the case.

In each case we have muscle action, resulting from a nerve impulse originating in a nerve center. In the one case the impulse arises from a reflex, the purpose of which is to effect *clear* vision; in the other, from a reflex whose purpose is to effect *single* vision. In the former case the impulse arises and is stopped by the action of the cyclo-

plegic at the nerve endings in the muscle. In the latter the conditions which start the reflex action are absent and consequently no impulse arises in the center; or, to put it briefly, in cycloplegia no impulse reaches the muscle because it is stopped at the nerve endings; in the "Prolonged Occlusion Test" no impulse reaches the muscle because none originates in the center for fusion.

It is obvious that of the three different types of tests for the relative position of rest, the cover or screen test is the only one suitable for a prolongation of the period of time for which it is used. Neither the diplopia tests nor tests of the Maddox rod type are adapted for prolonged use, and, moreover, they do not entirely abolish the tendency to fusion. The cover test on the other hand completely annuls binocular vision and makes any attempt to fuse impossible. Its mode of action is absolutely passive, if such a statement be permissible. It has the further advantage of being an objective test, its objective findings being also controlled by its subjective phase, the parallax test.

The "Prolonged Occlusion Test" is, in other words, nothing but a screen test extended in point of time. Theoretically, and practically when convenient and expedient, the test should last until stability in the position of rest is attained, that is, until the findings are essentially the same from day to day; but as a rule a week's occlusion will furnish valuable information.

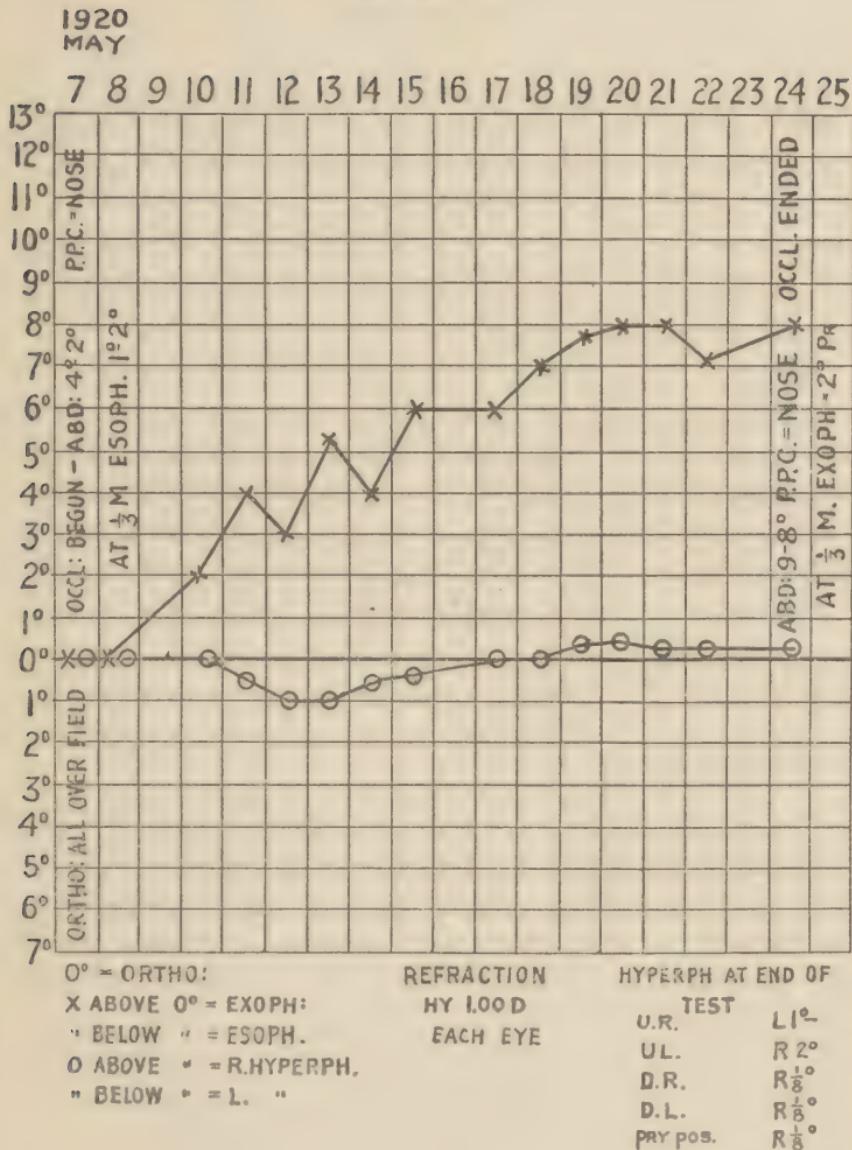
The question has been raised whether such prolonged occlusion does not induce an artificial dissociation,* but treatment based on its findings is so much more satisfactory than under ordinary conditions, and repeated tests are so consistent with one another that it seems to the

* See Appendix.

writer that this question should be answered in the negative. Moreover, what artificial condition can occur? Muscles are capable only of different degrees of contraction, a maximum contraction being the response to a maximum innervation, and a minimum contraction (*i.e.*, a maximum relaxation) being due to a minimum innervation. The muscles in their function of maintaining binocular single vision (convergence) are subject to innervation from two sources only: First, that due to the fusion power itself; and second, that due to the association of accommodation with convergence. In this test all attempts at fusion, and consequently all innervation due to attempts at fusion, are abolished by occluding one eye, and all excessive accommodation by a full correction of refractive error in the working eye. Under these conditions it is reasonable to expect that muscle spasm, due to long continued over-innervation from either of these sources, will in time pass away and the muscles resume their normal tone or state of maximum relaxation, in a state of minimum innervation.

It must be admitted at once that there is no means of knowing absolutely when this state of minimum contraction (maximum relaxation) has been reached, and, therefore, of knowing precisely what the relative position of rest is, but it seems likely that when observations made from day to day become stable for several days in succession, an approximation to it at least has been reached; and when circumstances do not permit the test to be maintained long enough for stability to be attained, that the general tendency shown by a curve plotted out in accordance with daily observations points, at any rate, in the direction of the truth, even if the whole truth is not revealed.

CHART I.



It is instructive, in this regard, to examine the charts here presented, showing the gradual development of the error in three members of the same family. It will be observed that there is a gradual increase of error in the case of R. M., Chart I, with some variation until the thirteenth day, after which date the amount of exophoria remains practically unchanged. If some artificial dissociation has taken place, this must have happened at some point between the first and thirteenth day of the test, but the chart gives no indication of anything but a gradual relaxation until stability is reached.

Chart II, Mrs. M. F. W. (sister of R. M., Chart I), is still more striking, because at an earlier period of life an exophoria of 20° had been diagnosed. This had been reduced by exercises to 7° , without any relief from symptoms. A Prolonged Occlusion Test brought the error gradually up to 19° .

Chart III, A. M. (brother of two preceding), shows also a development of the same kind of error. That the test in these cases brought out real and not artificial associations was confirmed by the fact that treatment based on the findings was beneficial in each.

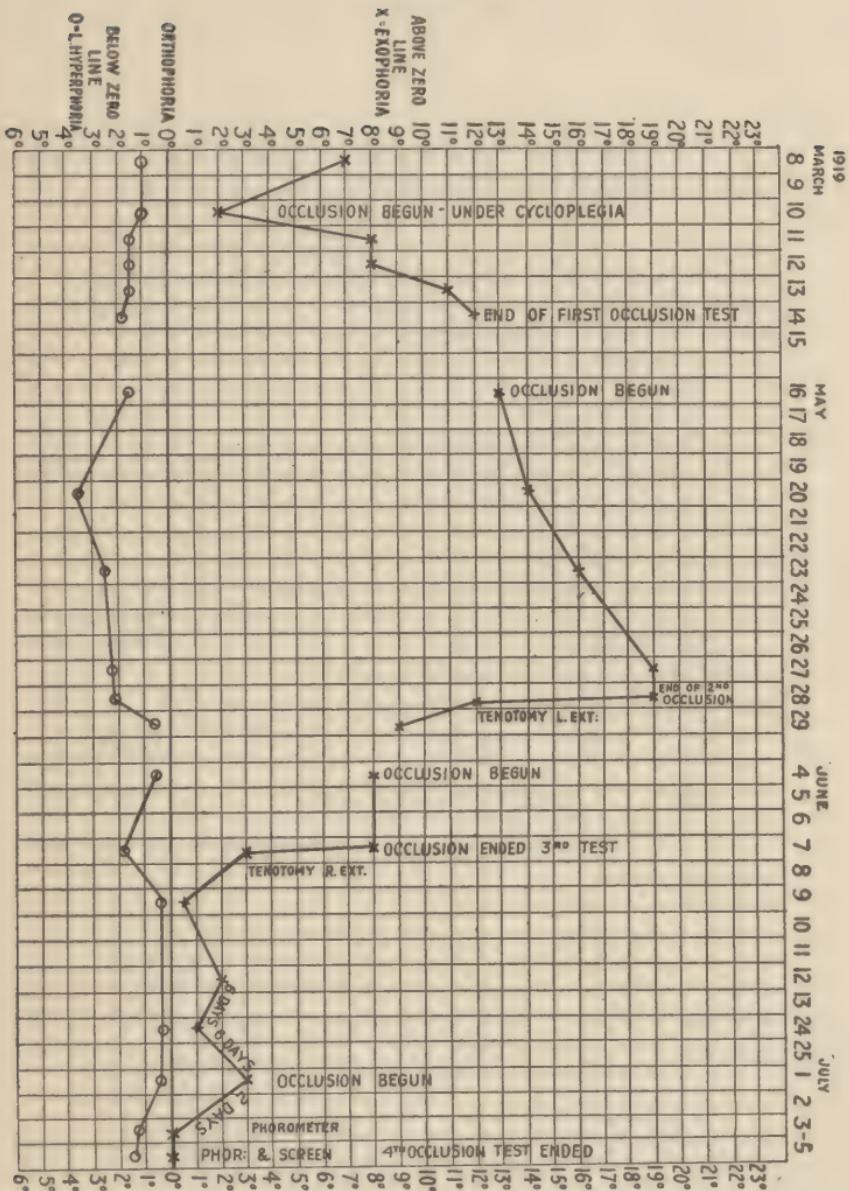
In the series of cases here presented I have seen no reason for thinking that the test is ever actually misleading, although cases occasionally occur which are difficult of interpretation at the present time. It seems probable that the method, instead of inducing, gets rid of artificial conditions and permits the true underlying relations to be seen. One of the points which emerge from the mass of observations is that vertical deviations are exceedingly common, and almost all apparently due to weakness or insufficiency* of one or sometimes more than one muscle.

* Possibly paretic but for reasons which will appear later, I am abstaining from the use of this term.

INTRODUCTORY.

7

CHART II.



8 . POSITION OF REST AND OCCLUSION TEST.

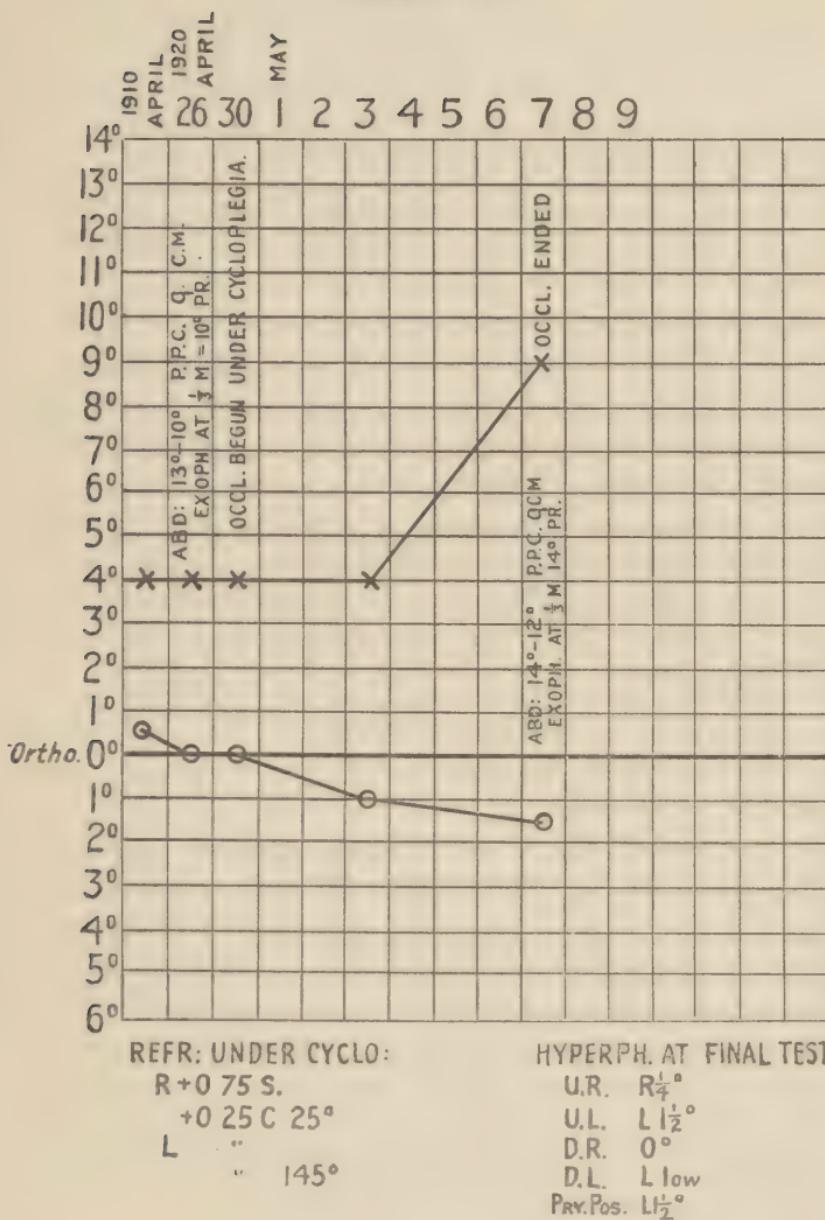
Let us consider the effect of an insufficiency of the R. superior rectus upon the binocular function, and the effect of occlusion in analyzing it:

- (1) The right superior rectus, being insufficient, requires excessive innervation to hold the R. eye on a level with the L. eye in movements up and to the right.
- (2) This excessive innervation is also communicated to its associate in upward movements to the R., the L. inferior oblique.
- (3) Diplopia due to overaction of the L. inferior oblique would result if its direct antagonist, the L. superior oblique, did not counteract this tendency.
- (4) The excessive innervation of the L. superior oblique necessary for this purpose would be communicated to its associate in movements down to the R., the R. inferior rectus.
- (5) Diplopia would result if the action of the R. inferior rectus were not held in check by its direct antagonist, the R. superior rectus, thus putting an extra demand upon the insufficient muscle.

A vicious circle in other words is formed. Binocular vision is maintained so constantly in such cases that no doubt spasm of the extrinsic muscles, strictly analogous to accommodative spasm in hypermetropia is induced, which obscures the deviating tendencies as effectively as the latter renders hypermetropia latent, and the total result of the activities described as revealed by the ordinary short test may even be orthophoria (functional).

If now the R. eye be occluded, fusion is made impossible, and consequently there will be no effort to maintain

CHART III.



it; excessive innervation of the R. superior rectus will cease, and consequently will not spread to its associate in upward movements to the R., to be counterbalanced as above described. In fact all abnormal innervation and all attempts at fusion cease and the eyes gradually assume their relative or anatomical position of rest, experience in a large number of cases showing that many days of rest are necessary in many cases to permit relaxation to take place.

The adoption of the method was brought about by the consideration of certain clinical observations. In the first place the well-known facts that a squint is apt to develop in children or adults, the subject of any condition such as corneal ulceration, annulling binocular vision for any length of time, that it develops not infrequently in patients who have had one eye bandaged for any length of time, and that a divergence or other deviation develops in many eyes (but not in all) which have become blind or very defective from any cause, would at least suggest that the duration of the annulment of the binocular function is an important factor in the detection of faults in the muscle balance.

In the second place, the common clinical observation, which makes the foregoing inference of practical importance, that there are a great many patients, the character of whose symptoms leaves no doubt that they are the subjects of some kind of eye-strain, who fail more or less completely to receive benefit from an apparently accurate correction of the manifest refraction and muscle errors, or are made worse by such correction, can only be explained on the theory that some etiological factor has been undetected or is not demonstrable.

A case also occurred in my practice, the facts of which strongly suggested the value of Prolonged Occlusion. The

patient was suffering from a burn of the eyelids of one eye from molten iron, necessitating the bandaging of the eye for a week. When the bandage was removed at the end of the period he complained of seeing double, and examination showed an exotropia of 5° to 6° and a hypertropia of 1° to 2° . Seven days after removing the dressing no fault in the muscle balance could be found. A 1° prism placed in any position destroyed the orthophoric condition. This man had been under the care of Dr. George T. Stevens some years previously for diplopia. The treatment, which consisted of prism exercises, had apparently succeeded in making the deviation latent.

The inferences to be drawn from this case seem to be that a week's occlusion is sufficient, at any rate in some cases, to render a latent deviation manifest, and that while exercises may improve the muscle tone or stimulate the function of the nerve center they do not cure the deviation.

CHAPTER II.

THE METHOD.

The test may be carried out practically by substituting a ground glass for one of the patient's lenses, or by pasting a piece of dark paper over the back of one lens, or by covering one eye with a black patch. Of these three methods the ground glass has the great advantage of comparative inconspicuousness, and is quite efficient, but the glare caused by light shining upon it is annoying to many neurotic patients, some of whom do not tolerate it. In such cases the dark paper or black patch can be substituted with advantage and success. A full correction of the refraction is worn over the other eye.

It is obviously not a matter of indifference which eye is covered. If a latent deviation be present and due to a paretic muscle the result will vary according to the selection made. As it is not always possible to determine this before the test, the selection must often be made on other grounds. In the series of cases upon which this article is based, this was decided in some cases by difference in visual acuity, the more defective eye being occluded, and in other cases—the great majority—by allowing the patient to decide whether he was right-eyed or left-eyed by sighting a distant light through a ring held at arm's length, both eyes being open, or by some analogous method. If he sighted the light with the right eye the left was occluded. Incidentally this test showed the right to be the "master" eye in a very large majority of the cases.

Dolman has shown (*Amer. Jour. of Ophth.*, April, 1920) that in ordinary tests for heterophoria a greater

amount of error is demonstrated in 66 per cent. of the cases, when the sighting or master eye is used to fix the light, though the difference is quite moderate in degree.

This is contrary to what one would expect if the deviation were paretic in nature for it is in accordance with common experience that the non-paretic eye is selected for fixation, unless its visual acuity is decidedly below that of the other, and the primary deviation is always less than the secondary. This criticism is not made to raise any question as to the essential accuracy of Dolman's observations, but to point out that as far as they go, they are not in harmony with the paresis theory.

I was under the impression, until I actually counted my cases, that the determination of the sighting eye had some relation to the weak muscle, but a correlation of these two factors in 109 cases in which both were carefully noted fails to reveal any such relation.

In 55 cases, or 50 per cent., the non-paretic eye was selected for sighting a distant object.

In 37 cases, or 34 per cent., the eye with the insufficient muscle was selected for sighting a distant object.

In 17 cases, or 16 per cent., there was an insufficient muscle on each side, and of these cases the R. eye was the sighting eye in 13 cases.

Of these 109 cases the R. eye only was affected (*i.e.*, had one or more weak muscles) in 39 cases.

The L. eye only was affected in 54 cases.

Both eyes were affected in 16 cases.

In all three groups the right is the sighting eye in a large percentage of the cases.

In cases of R. insufficiency, in 31 out of 39 cases, or in 80 per cent.

In cases of L. insufficiency, in 50 out of 54 cases, or in 92 per cent.

In cases of R. and L. insufficiency, in 13 out of 16 cases, or in 81 per cent.

Evidently the determination of which shall be the sighting eye depends but little, if at all, upon the presence of insufficiency of any muscle or muscles, and this observation also is not favorable to the paresis theory.

Just as most people are right-handed, so most are right-eyed, but the two functions do not always go together.

But it has been necessary not only to occlude one eye but also to create in the patient a state of mind which will prevent him from nullifying the value of the test in the many ways which can easily be imagined. Therefore, only those patients have been selected for the purpose who, by a combination of intelligence and a sincere desire to rid themselves of serious or annoying symptoms, have seemed suitable for it. In the next place the object and way of working of the test have been thoroughly explained to them, and finally they have been warned in detail of the precautions to be taken to avoid giving the binocular function an opportunity to be active. I have been surprised at the willingness with which it has been accepted by patients, and at the conscientiousness with which it has almost invariably been carried out.

To be specific, the directions given to the patient are that he shall put the glasses on in the morning before opening his eyes, that he shall not look over or under them, that if he wishes to remove them for any purpose—as washing the face—during the day, he shall close his eyes or at least one of them before doing so and replace the glasses before re-opening them, and that he shall wear them until after he has closed his eyes at night. In other

words that one eye must not be allowed to associate with the other during the whole period of the test. Strict continuity is apparently a very important detail. It was my good fortune to come across a case previously in the hands of one of my colleagues, in which sufficient emphasis had not been laid upon this point. Through his courtesy I am able to give the results of a seven and also a fourteen day occlusion test in which the patient did *not* put his glasses on until after dressing.

Before the first occlusion test, examination showed an exophoria of $\frac{1}{2}$ degree and no hyperphoria.

After the seven day test the exophoria rose to $1\frac{1}{2}$ degrees and there was left hyperphoria of $1\frac{1}{4}$ degrees.

After the fourteen day test the exophoria was 2 degrees and the hyperphoria again $1\frac{1}{4}$ degrees.

A ten day test *without any break in its continuity* gave exophoria 7 degrees and left hyperphoria 3 degrees.

Before beginning the test the patient is also warned in detail as to the loss of judgment of distance, and cautioned about walking up and down stairs, stepping into and out of cars, etc.

At the end of the period of occlusion, or whenever a test of the muscle balance is made during it, a full correction of the refraction is placed in a trial frame, with a Maddox rod, or whatever other means is selected for the test, the patient is directed to close his eyes, and his glasses are removed and replaced by the trial frame. He is directed to open his eyes, and the test is then made, without any break in the continuity of occlusion. It is my usual practice to use the Maddox rod for the vertical, and the phorometer or vertical diplopia test for the lateral

deviations, with the screen and parallax test as a confirmatory test. The difference between these tests is not always in favor of the screen test, and is negligible compared with the change occurring under prolonged occlusion.

It is impossible to emphasize too strongly the necessity of extreme care in carrying out the details of this test. If the occlusion be not continuous but broken, if the final test be not made with the strictest precaution for avoiding binocular fusion, the value of the test is probably much diminished, but if all the precautions necessary are taken, and the patient does his (usually her) part, as is almost invariably the case, it is of high value always, for it does one of two most desirable things; either it provides information which makes it possible to give the desired relief completely or partially, or it enables one to make the patient understand why relief cannot be attained.

DURATION OF TEST.

The length of time necessary to effect a complete relaxation of the muscles is in doubt. In the majority of cases the final test has been made at the end of a week's occlusion, and the result accepted for working purposes; but in a considerable number, daily observations have been made for the purpose of watching the mode and rapidity of the manifestation of the error and the period necessary to reach stability.

Reference may be made here again to Chart I, which shows the manifestation of an 8° exophoria in a man having perfect orthophoria all over the field at the pre-occlusion test. There was no break in the continuity of the test, the patient, at first quite reluctant to adopt it, finally becoming much interested in it. It will be noted that a 24-hour occlusion had no effect whatever in bring-

ing about any relaxation of his muscles, and that it was not until the thirteenth day that the highest degree of error showed. The test was continued five days longer without increase in the degree of error. It is also worthy of note that there was an occasional return of spasm as indicated by the irregularities in the curve. These were temporary only and there can be little doubt that the real position of rest was indicated by the highest point in the curve.

Light is thrown also on the question of the necessary duration by repetition of the test.

Thus in 72 cases a second test has been made at varying intervals after the first.

Briefly stated :

In 6 cases no change took place in either the vertical or lateral deviations.

In 14 cases no change took place in the lateral deviation.

In 24 cases no change took place in the vertical deviation.

In 33 there was an increase in the hyperphoria.

In 31 there was an increase in the exophoria or diminution in the esophoria.

In 15 there was an increase in the esophoria or diminution in the exophoria.

In 4 there was a diminution in the hyperphoria.

These changes were for the most part small in degree. Thus, there were only 17 cases in which the lateral change amounted to more than 3° , and only 20 in which the vertical change amounted to more than 1 degree. So far as the actual changes are concerned they confirm the value of the first test as being reliable so far as it goes. Thus, in 4 only of 72 cases did this second test diminish

the hyperphoria, the amount of diminution not exceeding 1 degree.

In 45 of the cases, exophoria remained the same or increased.

On the whole, the figures give a high value to a week's occlusion, but show that in some cases it fails to bring about a complete relaxation.

CHAPTER III.

THE RELATIVE POSITION OF REST.

IN a paper by Bielschowsky, read before the Heidelberg Ophthalmological Society and abstracted in the Archives of Ophthalmology for January, 1914, the relative position of rest is defined as the *position the eyes assume when uninfluenced by any innervation due to the power of fusion*. The author admits the difficulty of determining it, because the influence of the fusion power cannot be sufficiently excluded. He, therefore, determined it in 289 cases in which binocular vision had been lost by disease of one eye.

His results are as follows:

	Per cent.
Practical parallelism in	20 to 25
Divergence of 2 degrees or more in	60 " 70
Divergence with hyperphoria in	5 " 10
Convergence of 2 degrees or more in	10

The longer binocular vision had been lost the greater was the percentage of high degrees of strabismus. *Length of time of annulment of the binocular function is then an important element in determining the position of rest.*

In the 700 cases upon which this monograph is based the periods of occlusion were as follows:

	Cases		Cases
1 day	2	11 days	8
2 days	5	12 "	7
3 "	7	13 "	2
4 "	16	14 "	12
5 "	24	15 "	2
6 "	33	16 "	1
7 "	438	17 "	1
8 "	65	19 "	1
9 "	44	22 "	1
10 "	30	27 "	1

The relative position of rest at the end of these periods was found to be:

	No.	P. C.
Parallelism in	24	3.4
Divergence without hyperphoria	86	12.2
Divergence with R. hyperphoria	171	24.4
Divergence with L. hyperphoria	287	41.0
Total divergence	544	78.0
Convergence without hyperphoria	16	2.2
Convergence with R. hyperphoria	35	5.0
Convergence with L. hyperphoria	42	6.0
Total convergence	93	13.2
Hyperphoria without lateral deviation	39	5.5
Hyperphoria with lateral deviation	554	79.0
Total hyperphoria	593	84.0

In these statistics lateral deviations of less than 1° , and vertical deviations of less than $\frac{1}{2}^\circ$, have been ignored. Degrees refer to the angle of the correcting prisms.

It is true that the two groups of cases are not strictly comparable, as in the former the loss or impairment of vision of one eye is the only common factor, whereas in the latter the grouping is due to the presence of unrelieved asthenopia of one type or another in all, and therefore some anomaly of the muscle balance is, on the whole, probable.

Moreover, on account of the conditions under which Bielschowsky's examinations were made, the fact that in those cases in which the measurement was made by observation of corneal reflexes, the angle gamma was neglected, and the refraction apparently not corrected, the results must be regarded as approximate only. In view of the

association of convergence with accommodation it would seem that the effect of all refractive errors causing activity of the ciliary muscle should also be eliminated and that Bielschowsky's definition should be amended accordingly. In the cases here recorded the refraction was fully corrected.

CHAPTER IV.

ORTHOPHORIA.

It should be superfluous at this time to discuss just what conditions constitute orthophoria, but an examination of various text books and monographs as to its definition brings out such great differences, that for the purpose of discussing it here with clarity, it is necessary to state precisely what is meant by it. Conversation with colleagues also suggests much indefiniteness and vagueness of thought about this matter.

I find the following definitions:

- (1) Stevens' original one, "A tendency of the visual lines in parallelism," to which was added later, "when the minimum impulse is sent along the nerves governing the ocular movements."
 - (2) "The condition in which muscular equilibrium is maintained with the minimum of nervous effort."
 - (3) "That state of perfect equilibrium in which both eyes continue to be accurately directed at the object looked at, even when the controlling influence of the fusion sense is temporarily withdrawn."
 - (4) "When the visual lines meet at the object towards which they are directed, the condition is known as orthophoria."
 - (5) "Perfect muscle balance."
 - (6) "When the co-ordination is so perfect that when the eyes are directed towards an object, the visual lines correspond, and the images of the object
- (22)

fall upon corresponding points in the two retinæ, the condition is known as orthophoria."

- (7) "Right tending, or muscular balance."
- (8) "If a person looking with both eyes fixates the same object with both eyes, under all conditions, even for example when the image in one eye is artificially made different from that of the other, or is suppressed by covering one eye, he is said to have orthophoria."
- (9) "Orthophoria is the term applied to a perfect balance of the ocular muscles when the head is in a primary position and the eyes are looking straight forward with practical infinity at a dot or small light" and the "same equilibrium is maintained in all secondary and convergent positions."
- (10) "A condition in which both eyes look straight at the same object whether both see it or not. There is not even a tendency to deviation."
- (11) "The oculo-muscular state in which the visual axes tend to remain parallel when the eyes are adjusted for distance, and to converge properly upon the point of fixation for other distances."
- (12) "Perfect binocular balance."

The first two only can be said to be correct.

The fourth and sixth and perhaps the ninth are definitions of binocular fixation, and are as true of any case of heterophoria as of orthophoria.

The fifth and seventh, also the twelfth, simply substitute other phrases, without definition or explanation.

The third, eighth, tenth and eleventh are incomplete in that they make no reference to the essential condition of a minimum innervation of the extrinsic muscles.

What emmetropia is to the refraction of the eye, orthophoria is to its muscle balance.

Emmetropia exists when *parallel rays* of light are brought to focus on the retina, *the accommodation being in a state of minimum innervation.*

Orthophoria exists when the *visual lines are parallel*, the *extrinsic muscles being in a state of minimum innervation.*

The day has long gone by when a determination of the static refraction without cycloplegia would be considered valid, except in old age.

But definitions of the muscle balance, and its anomalies, and of the tests for its determination refer exclusively to the functional conditions, without any attempt being made to insure or induce a maximum relaxation, that is, a minimum innervation of the muscles.

That this functional position of rest does not necessarily represent the truth has been long recognized.

Hansen Grut, in his Bowman Lecture of 1890, says: "There are reasons for believing the parallelism found in the ordinary manner of making the examination to be often a position of *functional* rest which, in many cases, conceals a structurally divergent position of rest."

Though a divergent position of rest is without doubt far more common than a convergent one, the observations here recorded show that convergent, and far more commonly vertical deviations, may also be concealed, presumably by what Grut terms "habit," that is, the habit of maintaining parallelism and so inducing a secondary spasm.

Stevens, of course, recognized fully that manifest findings might leave more or less error unrevealed, and used prisms partly correcting the manifest error, for the purpose of inducing further muscle relaxation.

Nevertheless, I believe that it is true today that when no deviation is found by the screen, diplopia or rod tests, the condition is recorded as orthophoria and dealt with as such, usually no attempt being made to induce a minimum innervation of the extrinsic muscles.

Having unfortunately no drug analogous to the cycloplegics to eliminate the innervation of the extrinsic muscles we must fall back upon physiological principles and bring about a minimum innervation by removing all stimulus thereto; *viz.*, by making all efforts at fusion impossible by occluding one eye, by fully correcting all refractive errors in the working eye, and by allowing sufficient time to elapse for the spasm to become relaxed.

The cases here recorded have been dealt with in this manner, and it seems safe to assume that the results approximate the truth more closely than those obtained without the precautions detailed.

Although not strictly analogous, this method may be compared with that for establishing the limit of complete dark adaptation by keeping the eyes in the dark until they cease to vary as to thresholds. In the former case all stimulation of a center—that for fusion—is withheld, in the latter all stimulation of nerve endings. In each case the function of the part involved is tested at the end of a period of complete rest.

CHAPTER V.

TABULATION AND ANALYSIS OF CASES AND SOME INFERENCES TO BE DRAWN THEREFROM.

AMONG the 700 cases upon which this report is based are 154 in which the pre-occlusion test showed orthophoria.

TABLE 1.

ORTHOPHORIA BEFORE.

		DEVIATION AFTER OCCLUSION.																							
		ESOPHORIA								EXOPHORIA															
		8°	7°	6°	5°	4°	3°	2°	1°	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	16°
R. HYP.																									
L. HYP.																									
3°																									
2°																									
1½°																									
1°																									
½°																									
0°																									
½°																									
1°																									
½°																									
1½°																									
2°																									
3°																									
4°																									
5°																									
6°																									
7°																									
*																									

Table 1 shows the distribution of these cases among the different forms of heterophoria at the post-occlusion test.

* Figures within the squares show the number of cases having deviations corresponding to the horizontal and vertical scales. Thus there were 4 cases showing Ex. 4° and L. Hyp. 1°, one showing Exoph. 16° and Hyp. 0°, etc.

Stated briefly, of 154 cases of orthophoria before the occlusion test, only 13, or 9 per cent., were orthophoric after it; of the remaining 141 cases:

Exophoria, varying from 1° to 16°, developed in	21 cases or 13.6 per cent.
Hyperexophoria, varying from Hyp. ½° to 3°, Ex. 1° to 13° de- veloped in	97 " " 63.0 " "
Esophoria, varying from 1° to 8°, developed in	5 " " 3.2 " "
Hyperesophoria, varying from Hyp. 1° to 3°, Eso. 1° to 8° devel- oped in	4 " " 2.6 " "
Hyperphoria, varying from ½° to 1½°, developed in	14 " " 9.0 " "

To use Hansen Grut's expression, it may be said that orthophoria as ordinarily determined represents a "habit" acquired in the interest of single vision, and may not, and often does not, represent the truth as to the relative position of rest.

In the Ophthalmic Year Book for 1916, in concluding a review of Reber's paper on heterophoria, the writer of it says: "Patients with asthenopia in the presence of orthophoria have a general myasthenia and do not need an oculist, but an all-wise medical practitioner." This, no doubt, has been the common view, but in the light of the above observations evidently needs reconsideration.

What is true of orthophoria at the pre-occlusion test is true of all other pre-occlusion findings. They represent the degree of success which has been attained by the fusion power in establishing a habit of equilibrium, in the presence of deviating tendencies, or actual paretic (?) conditions.

The following tables show the character of the heterophoria at the pre-occlusion test and the change in the

degree and kind of error at the end of the period. Table 2 is compiled from the cases, 104 in number which showed pure exophoria before the test. Of these cases one only remained unchanged and of the remainder all but eighteen developed hyperphoria, R. hyp. 29, L. hyp. 56. In 7 cases the degree of exophoria diminished: 1° in two cases, 2° in four cases, 3° in one case, and in three cases esophoria of 2° to 5° developed. These cases of diminished exophoria are difficult to explain. It will be noted that the diminution is slight or moderate in degree. It will also be noted that the charts in which daily observations of developing exophoria are shown, show variations from day to day apparently due to temporary return of spasm, and had the test been stopped during one of these periods of spasm the exophoria would have been much less than it finally was proved to be. It is possible that in these cases of less post-occlusion exophoria, the duration of the occlusion was not long enough to bring about a complete relaxation of the muscles, and hence results which are perplexing and possibly misleading. It is also possible that just as in hypermetropia the accommodation sometimes acts to excess and produces a pseudo-myopia, so the extrinsic muscles may overcorrect a real esophoria causing temporarily an exophoria, though the reverse condition is far more common.

TABLE 2.

Exophoria without hyperphoria at pre-occlusion test, 104 cases. Amount of change in exophoria and of hyperphoria added.

	4°	3°	2°	1°	0°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°
R.HYP.																				
1°																				
2°			1																	
3°																				
4°																				
NO.HYP.																				
1°																				
2°																				
3°																				
4°																				
L.HYP.																				
1°																				
2°																				
3°																				
4°																				
AMOUNT OF CHANGE TO ESOPHORIA																				
NO CHANGE																				
INCREASE IN EXOPHORIA																				

— Decrease in exophoria.

Summary of Table 2.

Of 104 cases of pure exophoria at the pre-occlusion test—

Exophoria increased 1° to 16° in .. 95 cases or 91.3 per cent.

No change in 6 " " 5.6 " "

Decreased in 3 " " 2.9 " "

Hyperphoria of $\frac{1}{2}^{\circ}$ to 4° developed
in 85 " " 81.7 " "

(R. hyp. 29.)

(L. hyp. 56.)

In pure exophoria the final exophoria is almost always in excess of the primary measurement, and hyperphoria is present in 81.7 per cent. of the cases, L. being nearly twice as common as R. hyperphoria.

TABLE 3.

Cases with exophoria and R. hyperphoria before. 64 cases. Amount of increase in exophoria and changes in hyperphoria.

	5°				1															
DECREASE OR INCREASE IN R. HYP.	5°				1															
	4°																			
	3°				1	1		1												
	2°	1			-2	3					1	1								
	1½°		-1																	
	1°	-2	1	1	1		2	1½	1½	1										
	½°	2	-2	1½	1	1		1	1	1										
NO. CHANGE	2	-1	1	3	2	1				1										
	1°																			
AMOUNT OF CHANGE TO L. HYP.	½°						1	1												
	1°							2												
	½°								1	2										
	2°									1	2									
	3°										1									
	4°					1														
	5°						1													
	0°	1°	2°	3°	4°	5°	6	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°

Change in amount of exophoria.

— Decrease in hyperphoria.

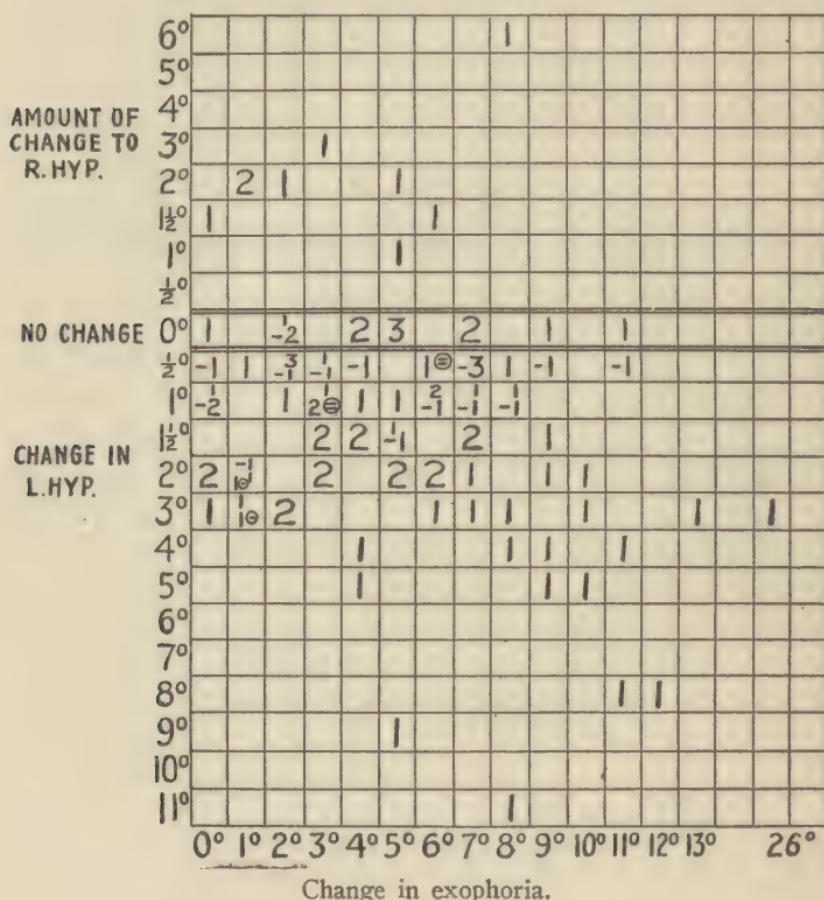
Summary of Table 3.

Of 64 cases of R. hyperexophoria at the pre-occlusion test—

Exophoria increased 1° to 14° in ...	56	cases or 87.	per cent.
No change in	7	" " 11.	" "
Decreased in	1	" " 1.5	" "
Hyperphoria increased $\frac{1}{2}$ ° to 5° in ..	25	" " 39.	" "
No change in	12	" " 18.5	" "
Decreased in	12	" " 18.5	" "
Changed to L. in	15	" " 23.5	" "

TABLE 4.

Exophoria with L. hyperphoria before. 99 cases.
Amount and kind of change after.



Change in exophoria.

— Decrease in hyperphoria.

(-) Decrease in exophoria.

(=) Decrease in both.

No mark = increase in both.

Summary of Table 4.

Of 99 cases of L. hyperexophoria at the pre-occlusion test—

Exophoria increased in	84	cases or 84.8 per cent.
Decreased in	6	" " 6. "
Remained unchanged in	9	" " 9. "
Hyperphoria increased in	59	" " 59. "
Decreased in	18	" " 18. "
Changed to R. in	9	" " 9. "
Unchanged in	13	" " 13. "

i.e., 22 per cent. changed from L. to R. hyperphoria.

In 163 cases of hyperexophoria, 99 are L. hyp. previous, and 105 after the test; 15 cases having changed from R. to L. and 9 from L. to R. The exophoria has changed to almost the same degree as in pure exophoria.

TABLE 5.

R. hyperphoria. No lateral deviation before. 74 cases.
Changes after.

	3°														
	2°	1	1	1	2				1	1	1				
CHANGE IN	1½°			1	-1	1									
R. HYP.	1°			2		3	-1	1	2	-1		1			
	½°			2	1	-1	-1	-1	-1	-3	-2				-1
NO CHANGE	0°			2	1	5	1		1	2					1
	½°														
AMOUNT OF	1°						1					1			
CHANGE TO	½°					3	2					1			
L.HYP.	2°		1	1		1	1	1		2	1				
	3°											1			
	4°									2					
	5°														
	6°														
	3°	2°	1°	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°
	ESO.														

— Decrease in hyperphoria.

Summary of Table 5.

Of 74 cases of pure R. hyperphoria at the pre-occlusion test—

Exophoria of 1° to 13° developed

in	65 cases or 88. per cent.
Esophoria of 1° to 3° developed in ..	3 " " 4. " "
No lateral deviation change in	9 " " 12. " "
R. hyp. increased $\frac{1}{2}$ ° to 3° in	29 " " 39. " "
Decreased $\frac{1}{2}$ ° to 2° in	14 " " 19. " "
Changed to L. in	19 " " 25.5 " "
No change in	13 " " 17.5 " "

R. hyperphoria increased or remained unchanged in 54½ per cent., decreased or changed to L. in 44½ per cent., and a lateral deviation developed in 92 per cent. of the cases. Exophoria in 88 and esophoria in 4 per cent.

TABLE 6.

L. hyperphoria. 72 cases. No lateral deviation before.
Changes after.

AMOUNT OF 2°					2			
CHANGE TO 1½°						1	1	1
R.HYP.	1°						1	1
NO CHANGE	0°	1			2	5	1	2
					-1	2	-1	-1
					3	-1	2	2
INCREASE IN	1½°	1	-1			1	2	
L.HYP.	2°				1	1	1	2
	3°						1	1
	4°				2		2	
	5°				1		1	
	6°							
	7°						1	
	8°				-1			
	9°							
	10°						1	
	8°	7°	6°	5°	4°	3°	2°	1°
	0°	1°	2°	3°	4°	5°	6°	7°
	8°	9°	10°	11°	12°	13°		

E50.

EXO.

— Decrease in hyperphoria.

Summary of Table 6.

Of 72 cases of pure L. hyperphoria at the pre-occlusion test—

Exophoria of 1° to 12° developed						
in	48	cases or	66½	per cent.		
Esophoria developed in	8	" "	11½	" "		
No lateral deviation developed in ..	16	" "	22½	" "		
L. hyperphoria increased ½° to 10°						
in	42	" "	58½	" "		
Hyperphoria decreased 1° to 2° in ..	9	" "	12½	" "		
Did not change in	12	" "	16½	" "		
Changed to R. hyp. in	9	" "	12½	" "		

In 77 per cent. of pure hyperphoria, exophoria 1° to 13° is latent. In about 20 per cent. the hyperphoria is reversed, this happening twice as frequently to R. as to L. hyperphoria. This would suggest that it is distinctly safer to prescribe prisms for a L. than for a R. hyperphoria, if no occlusion test be made.

L. hyperphoria increased or made no change in 75 per cent., decreased or changed to R. in 25 per cent.

TABLE 7.

Esophoria with no hyperphoria before. 55 cases.
Amount of decrease in esophoria. Amount of change to exophoria after. Amount and kind of hyperphoria added.

+ Signifies increase in esophoria.

Summary of Table 7.

Of 55 cases of pure esophoria at the pre-occlusion test—

Esophoria increased 1° to 12° in ...	7	cases or 12+	per cent.
Decreased 1° to 6° in	21	" " 38	" "
Did not change in	6	" " 11	" "
Changed to exophoria 1° to 10°			
in	21	" " 38+	" "
R. hyperphoria developed 1° to 3°			
in	21	" " 38+	" "
L. hyperphoria developed 1° to 4°			
in	21	" " 38+	" "
O. hyperphoria developed in	13	" " 23+	" "

Primary measurements of esophoria exaggerate it in 77 per cent. and in one-half that percentage there is a latent exophoria. Hyperphoria of from 1° to 4° is present in 77 per cent. of the cases. (80 per cent. in pure exophoria.)

TABLE 8.

Esophoria with R. hyperphoria before. 44 cases.
Changes after.

The figure is a scatter plot with the Y-axis labeled "AMOUNT OF CHANGE TO L.HYP." and the X-axis labeled "Decrease in exophoria".

- Y-axis scale:** -6°, -5°, -4°, -3°, -2°, -1°, 0°, 1°, 2°, 3°, 4°.
- X-axis scale:** -12°, -10°, -9°, -8°, -7°, -6°, -5°, -4°, -3°, -2°, -1°, 0°, 1°, 2°, 3°, 4°, 5°, 6°, 7°, 8°, 9°, 10°, 11°.
- Legend:**
 - Decrease in hyperphoria.
 - + Increase in esophoria.
 - No mark = decrease in esophoria.

Decrease in exophoria (X)	Amount of change to L.HYP. (Y)	Symbol
-12	-6	-
-10	-5	-
-9	-4	-
-8	-3	-
-7	-2	-
-6	-1	-
-5	0	-
-4	1	-
-3	2	-
-2	3	-
-1	4	-
0	-6	-
1	-5	-
2	-4	-
3	-3	-
4	-2	-
5	-1	-
6	0	-
7	1	-
8	2	-
9	3	-
10	4	-
11	-6	-
-10	-4	+
-9	-3	+
-8	-2	+
-7	-1	+
-6	0	+
-5	1	+
-4	2	+
-3	3	+
-2	4	+
0	-5	+
1	-4	+
2	-3	+
3	-2	+
4	-1	+
5	0	+
6	1	+
7	2	+
8	3	+
9	4	+

Summary of Table 8.

Of 44 cases of R. hyperesophoria at the pre-occlusion test—

Esophoria increased in	4	cases or	9.	per cent.
Decreased in	17	"	39.	"
Did not change in	4	"	9.	"
Changed to exoph. 3° to 10° in ...	19	"	42.+	"
Hyperphoria increased $\frac{1}{2}^{\circ}$ to 4° in	12	"	30.	"
Decreased in	11	"	25.5	"
Did not change in	8	"	16.+	"
Changed to L. 1° to 6° in	13	"	28.+	"

Primary esophoria is exaggerated in 81 per cent., in one-half that percentage masking exophoria of from 3° to 11° . The hyperphoria decreased, or changed to L., in 54 per cent. Therefore, in R. hyperesophoria there is a tendency to exaggerate the hyperphoria.

TABLE 9.

Esophoria with L. hyperphoria before. 34 cases.
Changes after.

AMOUNT OF CHANGE TO R. HYP.	2°							
	1½°	1°	2°			1°		
NO CHANGE	0°			1	1	2	1	1
	½°	-2	-1	-2		1	-1	-1
AMOUNT OF CHANGE IN L.HYP.	1°	1	2	1		1		
	1½°	1	-1					
	2°		1					
	3°	1	1+			1		
	4°							1
	5°							
	6°							
	7°							1
	12° - 4°	3°	2°	1°	0°	1°	2°	3°
	CHANGE IN ESOPHORIA	NO CHANGE	CHANGE	AMOUNT OF TO EXOPHORIA				

— Decrease in hyperphoria.

— Increase in esophoria.

No mark = Increase in hyperphoria.

No mark = decrease in esophoria.

Summary of Table 9.

Of 34 cases of L. hyperesophoria at the pre-occlusion test—

Esophoria increased in	2	cases or	5.7	per cent.
Decreased in	14	" "	40.	" "
Did not change in	4	" "	11.	" "
Changed to exophoria in	14	" "	43.	" "
L. hyperphoria increased in	15	" "	43.	" "
Decreased in	8	" "	23.	" "
Did not change in	6	" "	20.	" "
Changed to exophoria in	5	" "	14.	" "

Primary esophoria exaggerated in 83 per cent. and in one-half that percentage masking an exophoria from 1° to 7°. Tables show a less tendency for L. to change to R. hyperphoria than the reverse, 37 per cent. against 54.

Table No. 10 summarizes the general results of the test, showing the relative frequency of the different forms of heterophoria before and after it, and also the changes occurring in each form. Thus, there were 154 cases of orthophoria before the test, and only 24 after it. Eleven of

TABLE 10.

	BEFORE OCCLUSION				AFTER OCCLUSION							
	No. OF CASES	PER CENT	ORTHO.	EXO.	R.HYP. EXO.	L. " "	ESO.	R.HYP. ESO.	L. " "	R.HYP.	L. " "	
ORTHO.	154	22	13	21	37	60	5	1	3	5	9	
EXO.	104	14.9	0	19	28	54	0	1	2	0	0	
R.HYP. EXO.	64	9.1	0	10	39	15	0	0	0	0	0	
L. " "	99	14.1	1	9	9	80	0	0	0	0	0	
ESO.	55	7.9	2	4	8	9	7	13	12	0	0	
R.HYP. ESO.	44	6.2	4	7	6	6	2	13	6	0	0	
L. " "	34	4.9	2	2	1	11	2	4	11	0	1	
R.HYP.	74	10.5	0	10	35	17	0	2	1	8	1	
L.HYP.	72	10.2	2	4	8	35	0	1	7	0	15	
No. OF CASES	700	100	24	86	171	287	16	35	42	13	26	
PERCENT (AFTER OCCLUSION)			3.4	12.2	24.4	41	2.2	5.	6.	1.8	3.7	

these 24 had, however, shown some form of muscle imbalance (esophoria in the large majority) previous to the test, so that of the 154 cases of pre-occlusion orthophoria only 13 remained orthophoric at the end, the large majority developing hyperexophoria. The percentage of orthophoria falls from 22 before the test to 3.4 afterwards. Similarly esophoria almost disappears from the list, being reduced from about 8 per cent. to 2.2 per cent. The large majority of cases of apparent esophoria must be cases of pseudo-esophoria.

Pure exophoria falls from 14.9 per cent. to 12.2 per cent., and pure hyperphoria from 20.7 per cent. to 5.5 per cent. In other words, the deviating tendencies are more complex than they appear to be, the apparently pure lateral deviations having a latent hyperphoria, the apparently pure hyperphorias having a lateral deviation, usually exophoria. It is noteworthy that 574 cases or 82 per cent. showed hyperphoria at the final test, instead of 55 per cent. previous to it, cases of L. hyperphoria being 60 per cent. more numerous than those of R. hyperphoria. The percentage of cases of exophoria also rose from 38 to 77. The relative frequency of exophoria and hyperphoria will be referred to later.

It must be re-emphasized that these figures and percentages apply only to cases in which there are *a priori* reasons for suspecting the existence of a muscle error.

If Bielschowsky's definition of the relative position of rest be accepted, and no greater criticisms can be made of the prolonged occlusion method than those already advanced, and if the results tabulated above be conceded to be an approximation to the truth, which I see no reason to doubt, it must be admitted that tests for the muscle balance as ordinarily made leave the observer very much in the dark as to the degree of error present, and often mislead him as to its character. Consequently, the necessary correct data upon which alone a satisfactory diagnosis and therefore, therapeutic measures, can be based, are lacking in a very large percentage of cases.

This goes far to explain the unsatisfactory results commonly experienced in the treatment of these cases, a situation so unsatisfactory that so careful and experienced an observer as E. C. Ellett says:

"My personal experience is that the vast majority of cases of eye-strain are due to errors of refraction,

and not to errors of muscle balance. From the point of view of the results obtained and the methods by which they were obtained, I am sure that most of the time relief has followed the use of glasses, and when the glasses did not give the desired relief, no amount of muscle treatment by exercise, prisms or operation has given any considerable assistance." (Journal of The Tennessee State Medical Association, Feb., 1920.)

The method is free from the objections which are sometimes urged against the use of prisms either for diagnosis or treatment, being entirely passive in its mode of action.

It is, of course, true that the wearing of prisms to correct a portion of a latent deviation is followed in many cases by the manifestation of a higher degree of error, but it is also true that such manifestation occurs with greater rapidity and completeness under prolonged occlusion.

It seems desirable, therefore, to emphasize the great difference in the point of view brought about by the test and to consider the difference in the treatment which would be recommended before and after occlusion. The methods of dealing with these cases, aside from those concerning general health are three in number. (1) Exercises with prisms to strengthen the weaker muscles, (2) The constant wearing of prisms to diminish the work of the weaker muscle and (3) Operation to bring the visual lines nearer to parallelism.

First as to exercises—I have rarely seen any material or prolonged benefit from any form of prismatic exercises in my own practice, and in cases reported to me by patients previously seen by other men there has usually been no, or only temporary, improvement. Moreover, it must not be forgotten that no method of treatment carries with it

so large an element of suggestion as this. The patient sees two lights combining with greater facility and with stronger prisms from day to day, and naturally thinks that he is better, and it is unnecessary, in these days when psychic influences are recognized to play so large a part in matters of health, to lay any further stress upon this point.

Moreover, part of the apparent improvement is due to the patient's learning what may be called the knack of overcoming diplopia. An act essentially involuntary becomes partly voluntary.

Furthermore, even when improvement seems to have taken place in the muscle balance, as shown by a diminution in the degree of heterophoria, the symptoms are not always relieved, may indeed be aggravated, and an occlusion test may show that the improvement is apparent and not real, as the following cases show.

Mrs. L. E., age 35, came under observation in 1896, suffering from asthenopia and headaches. Examination revealed astigmatism of high degree and exophoria of 4° . She was given a full correction for her astigmatism and a $1\frac{1}{2}^{\circ}$ prism base in, in each lens. She remained comfortable until 1912, when her symptoms recurred. She then showed exophoria of 8° and the prisms were increased to $2\frac{1}{2}^{\circ}$ each eye. This failed to give the desired relief and in 1913 she showed an exophoria of 9° . Another change failed also to give relief, and she consulted another ophthalmologist, who prescribed prism exercises for distance, which she carried out for some months, without benefit. I saw her again in 1914 and found her exophoria reduced to 3° for 6 m. 14° to 16° at $\frac{1}{3}$ m. She was instructed to add exercises for the near point, but derived no benefit therefrom. A week's occlusion test brought the exophoria

up to 8° . Tenotomies (partial) of the externi gave a high measure of relief. (See Chart IV.)

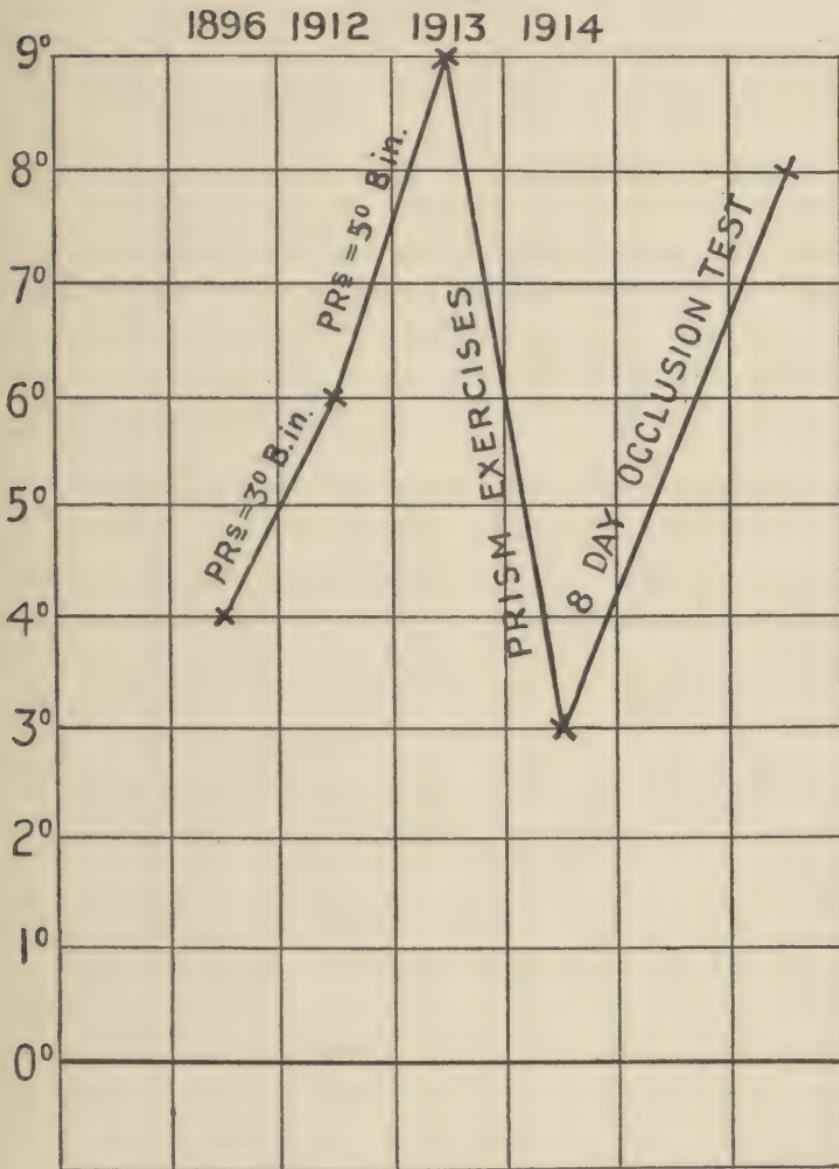
Mrs. M. F. W. (see Chart II), came under my observation at 39 years of age on account of intense sick headaches and other symptoms, which were thought by her physician to be of ocular origin. Twenty years previously an exophoria of 20° had been diagnosed by a well-known New York ophthalmologist. A long course of prism exercises was carried out, apparently reducing the amount of error and finally a 2° prism base in, over each eye, was prescribed for constant wear. The patient thought at the time that she received some benefit, but on looking back does not think the improvement amounted to much, and at best was temporary only.

When first seen by me, she showed an exophoria of 7° , which diminished to 2° under cycloplegia. A four day occlusion test brought the exophoria up to 12° , and a second test of 11 days brought it up to 19° , or within one degree of the original measurement.

Tenotomies of the externi, her p.p.c. being quite normal, effected a great improvement in her condition.

Moreover, if these errors are anatomical and congenital, as no doubt a very large majority of them are, it is quite unreasonable to expect that the position of rest can be changed by any amount of exercise, certainly not by that ordinarily prescribed, especially when consideration is given to the fact that the nature of the case itself has compelled constant exercise of the same muscles for the purpose of maintaining single V., from a very early period of life. The small therapeutic addition would appear to be negligible. From the standpoint of this test, the change in position of rest caused by exercises is apparent and not real.

CHART IV.



MRS. L. E. 23 - 41 CASE NO. 35 193

Exercises for convergence insufficiency with a white pin head or a black dot on a white card have resulted only exceptionally in an approximation of the near point of convergence.

The use of prisms for constant wear has been considered undesirable by Duane and others, especially in lateral deviations. They are said to increase the amount of error, and to weaken instead of strengthen the muscles. I have seen no reason, in cases coming under my observation, to attribute any importance to these considerations. There are obvious and unavoidable limitations to the use of prisms for constant use, the chief one being that they cannot be worn for the relief of one form of deviation without putting the eyes out of their normal alignment with the muscles acting at right angles to that deviation. Thus, if prisms are worn for a lateral deviation the visual lines lose their normal relation to the vertically acting muscles and a new source of strain is introduced. The practical effect of this varies with different individuals, some tolerating much higher degrees of prismatic correction than others. The dispersal of light by, and the weight and appearance of, strong prisms constitute other but less important objections.

The increase in the measure of the deviation following the constant use of prisms is better explained by the gradual manifestation of the latent error, and continues only until the latter error becomes completely manifest. A far more rapid manifestation of the error can be brought about by a prolonged occlusion test, which is free from the objection which may be raised against the possibly active effect of prisms. I have been in the habit of prescribing prisms for many years, and have yet to see a case in which the apparent increase of error could be better explained by the latter than by the former theory,

and in numerous cases no increase at all has taken place. Briefly, the claim is made that the prolonged use of prisms causes an actual increase in the error, *i.e.*, changes the anatomical position of rest. If this contention were true, it would place at our disposal a most effective means of curing these deviations. The problem of treatment would indeed be solved. But so far, no satisfactory evidence has been brought forward in favor of this position. What is commonly called the "Therapeutic Test," which is another variant of the old proverb that "the proof of the pudding is in the eating", also can be utilized to furnish evidence as to the value of prisms for constant wear. There are a great many cases, among which I must include my own, in which the patient obtains no, or very incomplete, relief until the faults in the muscle balance are detected and a prismatic correction included in the formula, and in a very large number of these cases the relief afforded is just as satisfactory and as permanent, as that which is attributed to the correction of hypermetropia and astigmatism.

The usefulness of prisms for constant use is limited for the reasons just stated to the lower degrees of error, the exact limits of which cannot be defined on account of individual variations of tolerance. (Further and more definite suggestions on the prescription of prisms will be made in the section on Treatment.)

By far the most important point in connection with the constant use of prisms and the occlusion test is, that the latter opens up what is practically an entirely new field for this method of treatment. Cases appearing by the ordinary tests as orthophoria or low degrees of heterophoria are shown to have degrees of error far greater than that shown by the primary tests, and consequently prisms can be prescribed in cases in which, without this

test, no indication for their use would be apparent. Moreover, as already suggested, cases measured in the ordinary way and dealt with by the constant use of prisms have errors often really of such high degree that the prisms prescribed correct too small a fraction of the total error to have any effect: hence the failure to give satisfactory or permanent relief.

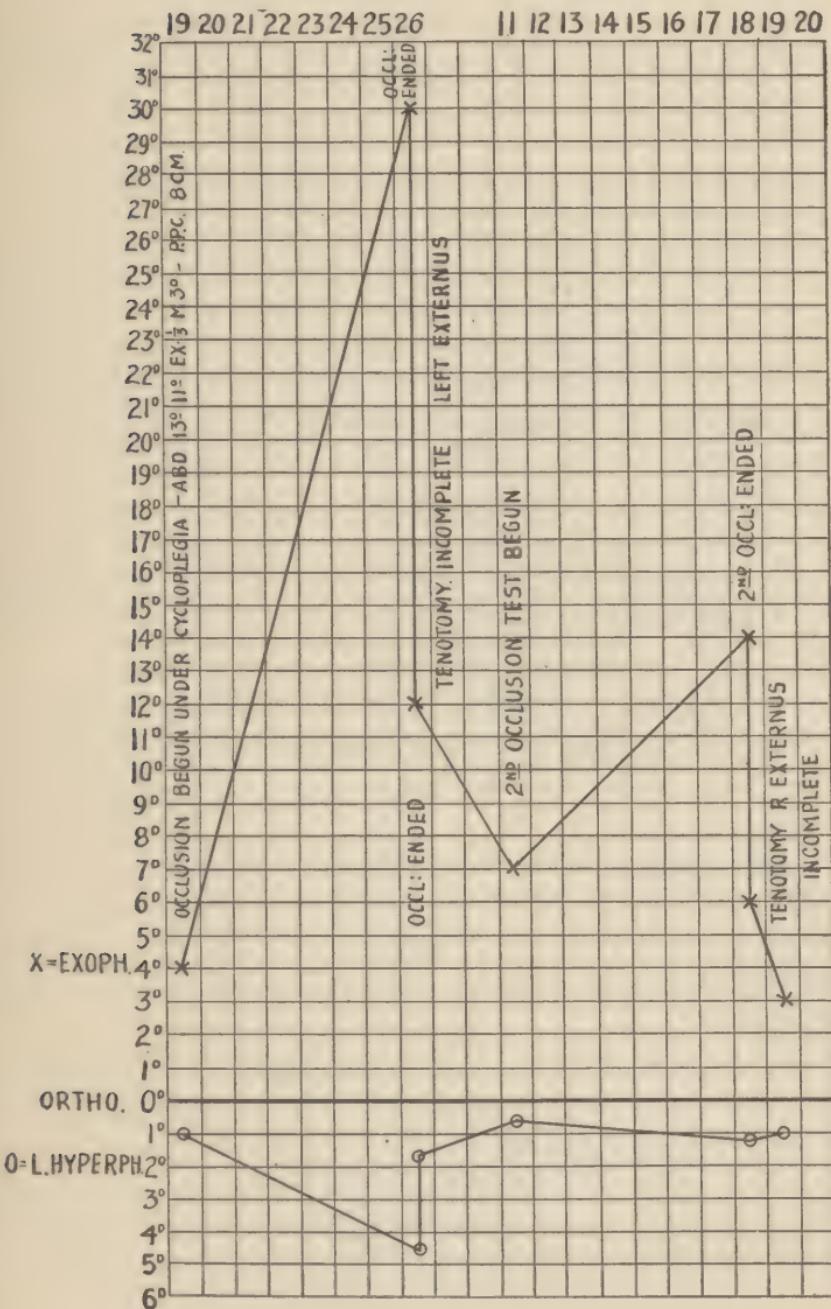
As regards operative treatment it is obvious in the first place that the kind and degree of error, and if possible the particular muscle or muscles at fault must be known if the operation is to be anything more than a haphazard procedure, and a little experience with the prolonged occlusion test will show that none of these factors can be estimated with sufficient precision without it. The muscle balance after operation also cannot be determined without it. These two considerations, ignorance of the condition previous to operation and ignorance of the effect of the operation go far to explain the ill repute into which these operations have fallen.

The great diversity of opinion as to the effect of a partial tenotomy is to be accounted for in the same way. As is well known the degree of error is often apparently unchanged. If, for example, we consider the case of Miss M. N. (Chart V), who showed at her first examination 4° of exophoria, which came up to 8° after prismatic measurement of her abduction, we shall note certain points of great practical importance. A week's occlusion raised the exophoria to 30° . If previous to occlusion partial tenotomy had been done, aiming at an 8° correction, disappointment would have been inevitable, both as regards the effect on the symptoms, and on the degree of error. No doubt an amount equal to that first noted would soon have become manifest, and the conclusion that partial tenotomy has no effect would appear to be justified. Similarly

CHART V.

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had prisms been prescribed for *constant* wear, disappointment would have ensued as to the relief of symptoms, and the error would have appeared to increase as a direct result of their use. These disappointments and erroneous conclusions can be avoided, as in this case, by a prolonged occlusion test.

The case of Mrs. C. A. T. shows what may underlie an apparently perfectly successful operation.

She was the subject of sick headaches of the most intense type, and eighteen years before I saw her consulted an ophthalmologist of national reputation who made an operative correction of her heterophoria, without giving any relief from her symptoms. This was in 1898. When I saw her in 1916, examination showed no lateral deviation and L. hyperphoria $\frac{1}{2}^{\circ}$. Under cycloplegia, the R. eye was emmetropic and the L. hypermetropic 0.50 D., and the muscle condition was Ex. 1° , L. hyperphoria 1° . An 8-day occlusion test brought the exophoria up to 14° , and the L. hyperphoria to $4\frac{1}{2}^{\circ}$.

On inquiry I learned that before operation she had an esophoria of 7° , and L. hyperphoria $1\frac{1}{2}^{\circ}$, and that operations were done on an internus and one of the vertical muscles.

The operative result was apparently good.

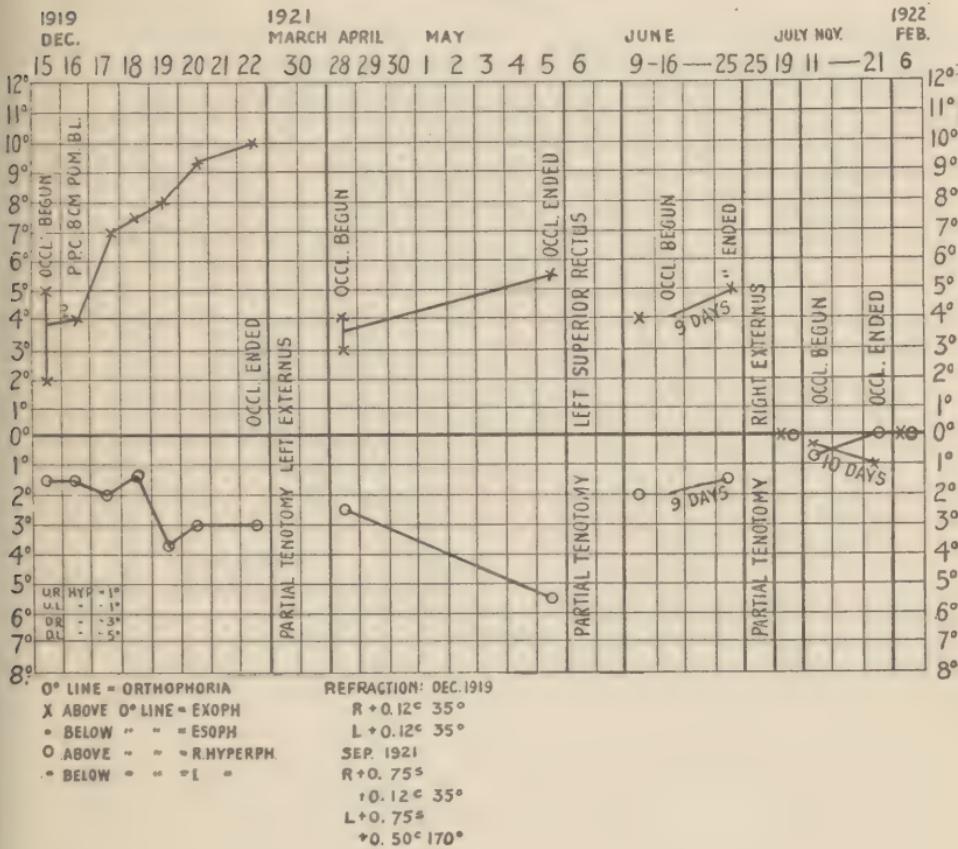
In the light of the occlusion test there must be some doubt as to whether this patient had originally an esophoria or not, and also what change was affected by operation.

I append here a chart of a case showing the effect of partial tenotomies, as demonstrated by occlusion tests before and after operation.

What has been said of the constant use of prisms and the new field opened up for their use by the "Occlusion Test," applies equally emphatically to operative treatment.

It becomes obvious after the occlusion tests that operation is the only means of relief in many cases, in which the pre-occlusion test would not indicate it at all.

CHART VI.



CHAPTER VI.

MUSCLE BALANCE IN RELATION TO REFRACTION.

A correlation of the different forms of post-occlusion heterophoria with those of ametropia results as follows:

The cases have been arranged in three groups.

- (1) Those in which the refraction was hypermetropic.
- (2) Those in which it was myopic.
- (3) Those in which mixed astigmatism was present.

TABLE 11.

	HY. AND HY. ASTIG	MY. AND MY. ASTIG	MIXED ASTIGMATISM
ORTHO.	4. P.C.	2.9 P.C.	4.4 P.C.
EXOPH.	11.6 } 77	16.5 } 84.5	16.66 } 73.8
HYPER. EX.	65.4 }	68.00 }	57.2 }
ESO.	2.2	1.9	1.20
HYPER. ES.	8.8	3.9	6.00
HYP.	8.8	6.8	14.40

These figures cannot be said to have any value in confirmation of the theory, that the form of heterophoria has any relation to the kind of refraction present. The percentages of heterophoria vary but little in the three groups. They show a slightly greater incidence of exophoria in myopia than in hypermetropia, but the difference is diminished if the cases of mixed astigmatism, which are essentially cases of incipient myopia, are added to those of myopia. Then we find the muscle balance to be exophoric in 77 per cent. of the hypermetropic cases, and 79 per cent. of the myopia cases, a difference quite negligible.

The incidence of esophoria of all kinds in hypermetropia is 11 per cent., in myopia and mixed astigmatism $6\frac{1}{2}$ per cent., but as the total number of cases of myopia and mixed astigmatism is small (187) compared with those of hypermetropia (500), inferences drawn from these percentages may be misleading.

The incidence of pure hyperphoria in myopia and mixed astigmatism is slightly greater than in hypermetropia, 10.6 per cent. in the former, 8.8 per cent. in the latter, and when all hyperphorias are considered we find 83 per cent. in hypermetropia, and 78.7 per cent. in myopia, a difference without significance. On the other hand the absence of difference is significant because it suggests that hypermetropia may diminish and finally change to myopia without change in the average muscle balance. As one would expect upon evolutionary or developmental principles, exophoria is the commonest and esophoria the rarest in all forms of refraction.

If it be borne in mind that almost all eyes are hypermetropic or hypermetropic and astigmatic at birth, and that myopia is an acquired condition it will be seen that the tables quite harmonize with the supposition that heterophoria is of congenital origin.

We see cases of hypermetropia passing through what Risley called the "Turnstile of Astigmatism" into myopia, but this transformation is accompanied by no change in the position of rest. In other words what the position of rest was in hypermetropia it remains when the refraction changes from hypermetropia to myopia.

Variation is a well-recognized law of nature, and it would be quite unreasonable to expect that the ideal would be attained in the matter of the relative position of rest any more frequently than in other characters. Attainment

most frequently falls short of the ideal, occasionally reaches it, and occasionally overshoots it.

Those who regard the various forms of heterophoria as acquired conditions developing out of an original or congenital condition of orthophoria, necessarily assume a degree of perfection or uniformity in the binocular function, rarely if ever attained in any other character, physical or mental. To emphasize this point it is only necessary to refer to the color sense and the sense of musical pitch. Aside from well-recognized degrees of color blindness it is well known that the color sense of average normal individuals varies enormously, and that the ability to recognize and remember the pitch of musical tones varies similarly. These are simply variations in the perfection of nature's attainment. They are only two examples of the well-known law of variation. There is no justification for the assumption that nature will furnish each or any individual with orthophoria as a basic condition at birth.

CHAPTER VII.

AGE, HEREDITY AND EVOLUTION.

THE ages of the patients included in this series of cases vary from 9 to 78.

High degrees of error may remain latent until extreme old age, as in the case of Mrs. B. Mrs. K. P. B., aged 78, was subjected to a prolonged occlusion test because the correction of her refraction failed to make her comfortable.

R. V. $\frac{6}{9}$ with + 4.50 Sph. \bigcirc + 1.37 C 5°

L. V. $\frac{6}{9}$ with + 4.00 S. \bigcirc + 1.00 C 170°

No lateral heterophoria. Hyperphoria varied from low L. to low R. At the end of a seven day occlusion period, tests showed L. hyperphoria 5° and exophoria 10° .

That errors in the muscle balance in children may remain latent, until one eye becomes defective from traumatism or disease or has to be occluded by a bandage, is well known.

Table 12 shows the incidence of the various forms of heterophoria at different ages before and after occlusion.

The question whether heterophorias are congenital or acquired receives some illumination from an examination of this table.

If congenital they should be as frequent at one age as at another.

If acquired they should be of increasing frequency as age advances.

Particularly it should be true that occlusion would reveal a larger percentage as age advances, but the reverse rather is true.

In the second decade 32 per cent. were orthophoric at the pre-occlusion test, and one per cent. after it.

In the third decade 25 per cent. were orthophoric before, and 2½ per cent. after.

In the fourth decade 21 per cent. were orthophoric before, and 5 per cent. after.

TABLE 12.

AGE	No OF CASES	ORTHOPHORIA PRE-OCCLUSION	EXOPHORIA	HYPER-EXO	ESOPHORIA	HYPER-ESOPH.	ORTHOPHORIA	EXOPHORIA	POST-OCCLUSION HYPER-EXO.	ESOPHORIA	HYPER-ESOPH.	ORTHOPHORIA HYPERPHORIA
1-10	2	— CASE			— CASE					— CASE		
10-20	37	32.4%	11.4%	22.8%	11.4%	11.4%	13%	0	13% 65%	5.4%	2.7%	11.4%
20-30	200	25%	18.5%	20%	7%	13%	17%	2.5%	13.5% 69%	1.5%	6%	7%
30-40	217	21%	14.7%	24.8%	8.2%	12%	18.1%	5%	12.4% 64.5%	2.3%	8.2%	7%
40-50	151	11.9%	13.2%	25%	9.9%	9%	21%	2%	11.2% 66.8%	3.3%	5.3%	11.2%
50-60	68	11.9%	14.7%	25%	4.4%	13.2%	30.8%	5.9%	11.9% 58.8%	0%	8.8%	14.7%
60-78	20	25%	5%	25%	10%	5%	30%	10%	5% 40%	5%	15%	25%

A scrutiny of the table will show that the percentages of the different forms of error vary but little at different ages.

Comparing the prevalence of all exophorias, the commonest form at the post-occlusion test, at different ages we find:

78	per cent. from 10 to 20 years.
82½	" " " 20 " 30 "
77	" " " 30 " 40 "
78	" " " 40 " 50 "
70	" " " 50 " 60 "
45	" " " 60 " 78 " (20 cases only.)

Briefly, the table suggests that age has no bearing on the prevalence of heterophoria and that its congenital origin is the more probable. So far as it goes the table tends to

show a diminishing functional orthophoria with increasing years, and also a diminishing latency of imbalance.

That several members of the same family often present the same kind of error is a matter of frequent observation.

A boy, aged $6\frac{1}{2}$ years, the subject of ophthalmia nodosa complained, after the removal of the bandage worn for several days after operation, of diplopia which was found to be due to an exotropia of 8° , and a right hypertropia of 4° , which disappeared within two days after the bandage was left off. This boy's mother had been previously under my observation for symptoms due to an exophoria of 12° , and right hyperphoria of 1° .

The well-known occurrence of exophoria early in life, in several members of the same family, and in succeeding generations, would seem to suggest that it is congenital and anatomical in nature.

The great prevalence of exophoria as compared with esophoria can be best explained by evolutionary considerations. The visual lines have come up to a relation of parallelism from one of divergence, and a reversion to an earlier type is more probable than that nature should overshoot its mark.

Treacher Collins, in his exceedingly valuable and interesting Bowman Lecture, says:

"Animals, such as the terrestrial herbivorous mammals, who require panoramic vision, have their eyes set laterally in the head so as to obtain the largest circumferential effect of the combined monocular fields. Lindsay Johnson (3) measured the divergence of the optical axes in a large number of representative animals, and constructed a diagram graphically showing how it varies in the different natural orders, families, genera and species.

"This movement forward of the optical axes toward parallelism is clearly in the interests of binocular vision, and at the sacrifice of range of simultaneous circumferential vision. As ontogeny is a condensed recapitulation of phylogeny, it is interesting to note that in the human embryo the optic vesicles when first formed are directly opposite to one another from which position they gradually turn forwards, so that at the third month of fetal life the optic axis of each eye diverges 45° from the middle line; before birth they become parallel."

Just as few eyes attain that ideal refractive condition known as emmetropia, just indeed as few individuals attain the ideal in stature, proportion, mentality or any other character, so few individuals attain that ideal and most desirable perfection of muscle balance—orthophoria; the great majority fall short of it and are, therefore, exophoric.

Similarly prism-abduction is probably a survival from an earlier evolutionary period in which an active abduction served a useful purpose in panoramic or circumferential vision, and is therefore essentially a vestigial function; an assumption which would explain its great variability. The alternative hypothesis that it has been developed in response to the necessity of adjusting the visual lines to a point beyond infinity is unthinkable. May not the frequency of hyperphoria be accounted for in the same way? With panoramic vision it cannot be essential that the visual lines be in the same horizontal plane. In some animals they certainly have the power of moving out of it as in the chameleon.*

* Of this curious reptile, Gadow, in the Encyclopedia Britannica says, "The right and left eyes are incessantly moved separately from each other

May not sursumduction and deorsumduction also be due to the survival of this power of independent movement? Sursumduction and deorsumduction apparently serve no useful physiological purpose in man and those higher animals possessing binocular single vision. In whatever position the head is placed, single vision requires that the visual lines remain in that plane of the head in which the eyes converge for fixation of objects at different distances. If one visual line departs from that plane to the slightest degree confusion or diplopia must arise. Hence, hyperphoria, sursumduction and deorsumduction also, may represent a reversion to an earlier type.* It is perhaps not without significance that the percentage of hyperphoria is

and literally in every direction, up and down, forwards and straight backwards, producing the most terrible squinting." And yet "chameleons alone, of all reptiles, can focus their eyes on one spot, and conformably they alone possess a retinal macula centralis or spot of acutest binocular vision."

* These purposeless conditions and activities, namely exophoria and abduction, hyperphoria, sursumduction and deorsumduction may be placed in the same class as the persisting functions of the ear muscles in some human beings, which are conceded to be vestigial or rudimentary in character. "The power of erecting and directing the shell of the ears to the various points of the compass, is no doubt of the highest service to many animals, as they thus perceive the direction of danger." (C. Darwin: *The Descent of Man*.) Moreover, cases occasionally occur, and some are recorded in the literature of the subject, in which there are more definite reverersions to an earlier evolutionary type. Thus, W. L. Phillips, in *Am. Med.*, March 24, 1906, quoted in the *Practical Medicine Series* for 1907, reports two cases showing the preservation of ocular function existing normally in some animals. Thus X has V% in each eye and can fix with both eyes, and at the same time turn either one out and back again to fixation while reading, or converge or diverge both simultaneously, etc., without diplopia. The second patient could set type with one eye and read proof at one side with the other.

The writer has under observation a man with divergent strabismus, normal vision in each eye, ability to use either eye at will but with no convergence power. Two other members of his family are said to be similarly affected.

very close to that of exophoria at the post-occlusion test, 85 of the former, 75 of the latter. The causes which produced exophoria seem to have been even more effective in producing hyperphoria. Presumably the etiology is the same in both cases, for it would be quite superfluous to assume a different causation for each form when one will satisfactorily explain both.

If it be conceded that exophoria and hyperphoria are vestigial conditions arising from similar causes then it is unnecessary to assume a dependence of one upon the other.

Consequently, treatment need not be influenced by this assumption. The fact that hyperphoria seems in the large majority of cases to be due to weakness or insufficiency of one or more muscles does not necessarily invalidate this theory. It seems entirely improbable that an actual paresis should occur in anything like the percentage of cases in which hyperphoria can be demonstrated.

Whatever weight these considerations may possess must be placed in the scale against the theory that exophoria or hyperphoria is often an acquired condition.

It seems most probable that a developing exophoria or hyperphoria is a latent anatomical error undergoing gradual manifestation.

If exophoria is a congenital anatomical survival from an earlier evolutionary period it would seem extremely improbable that exercises of any kind would bring about an organic change, and this would be truer as age progresses. As already stated, the occlusion test furnishes a ready means of testing the actual effect of exercise on the position of rest. A small number of cases have come under my observation in which the exophoria has been apparently diminished by exercise, without, as a rule, any improvement in the symptoms. An occlusion test has brought out error of about the same degree as that present before using the exercises.

CHAPTER VIII.

ABDUCTION.*

ABDUCTION may be defined as the divergence of the visual lines *from parallelism* brought about by placing prisms, base in, before the eyes; the measure of it being represented by the strongest prisms with which single vision can be maintained.

It is not demonstrable under any condition except this artificial one.

The question is raised elsewhere as to its origin, and purpose or utility.

Stevens has pointed out that a low power of abduction does not necessarily exclude the presence of exophoria. "It happens not infrequently that with an abduction of only 5° there is, as shown by the phorometer, exophoria of one or more degrees." This is rather a vague statement as to the amount of exophoria which may exist under such conditions, but presumably the degree of exophoria would not be expected to exceed the degree to which the eyes could be forced outwards by the use of prisms placed base in; in fact such a relation of abduction to exophoria during the same examination is unthinkable. Yet observations made as to the degree of abduction before occlusion and the degree of exophoria after occlusion show that the latter not infrequently exceeds the former and sometimes very greatly. In other words the spasm of the interni brought on by constant efforts to overcome a diverging tendency cannot be induced to relax in response

* Used here only in the sense of prism divergence.

to the brief use of abducting prisms, but a prolonged annullment of binocular fusion will gradually effect this relaxation, raising both the degree of exophoria and that of the abduction. Thus, in the most extreme case I have seen, in which an exophoria of 4° (8° after testing abduction) and an abduction of 13° could be demonstrated at the primary examination, a week of occlusion raised the exophoria to 30° and the abduction to 31° .

Evidently, then, the pre-occlusion abduction does not necessarily bear any quantitative relation to the post-occlusion exophoria.

In recording abduction the points at which doubling occurs, and fusion is resumed have both been recorded. The point at which diplopia occurs (the ascending point) has been taken for the purpose of comparison with the final exophoria. Had the fusion point (the descending point) been regarded as the measure of the abduction, the number of cases in which the final exophoria exceeded the primary abduction would be far higher.

Table 13 shows the abduction before and after occlusion in 47 cases. In all but four cases there was an increase, sometimes a very great one, as from 1° to 10° , 6° to 13° , 9° to 17° , etc.

In three cases there was no change.

In one case there was a decrease of 1° .

It is evident that the pre-occlusion tests for abduction fail to reveal the total abducting power and are of low value. As a guide to the possible state of equilibrium, they are of still less value.

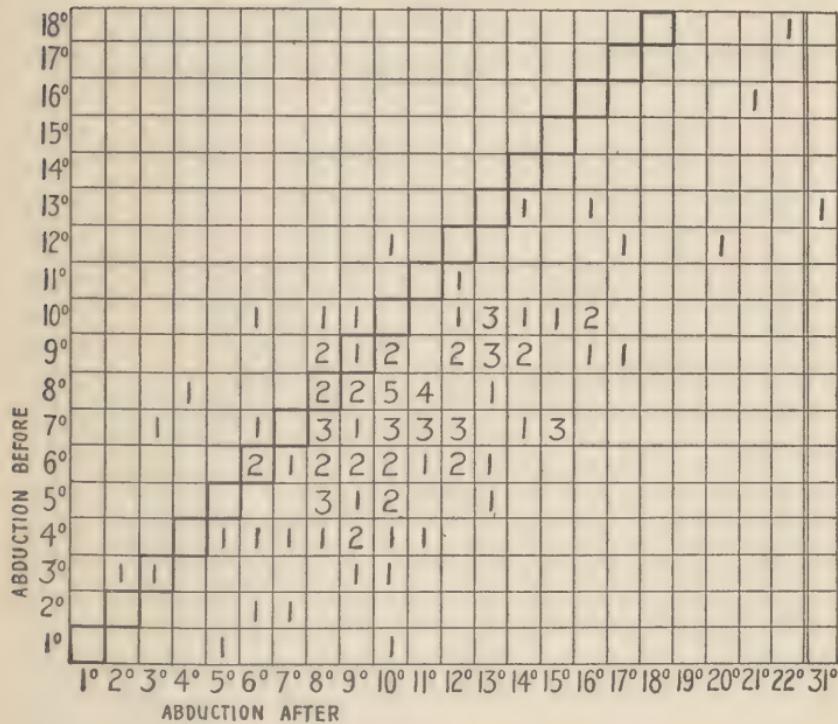
These observations raise two questions:

- (1) Which is to be the measure of abduction, the doubling point or the fusion point? In many cases they are not more than a degree or two

apart, but in others there is a difference of several degrees. In regard to this point it seems to the writer that the measurement just preced-

TABLE 13.

Change in abduction, 106 cases.



ing the doubling point is the true measure of the abducting power. Were the power of abduction less than this, diplopia must necessarily occur sooner. On the other hand the point at which the images fuse would seem to indicate the activity or sensitivity of the fusion center. To put it in other words the point of doubling is a sign of the limit of endurance, the point at which

fusion is resumed of the activity or alertness of the fusion center. It would seem that both the points should be recorded.

- (2) Is the abducting power properly represented by its measurement before or after occlusion? The analogy of the power of accommodation seems apposite. The power of accommodation is represented by the difference between a minimum and a maximum innervation. We must know the latent refractive error in order to measure the power of accommodation. Similarly we must have the extrinsic muscles in a state of complete relaxation to measure the abduction.

The post-occlusion test is the true measure of the abduction. Therefore, without an occlusion test we do not know the power of abduction.

Table 14 shows the relation between the pre-occlusion abduction to the post-occlusion exophoria as observed in 299 cases.

In 195 cases the final exophoria measured less than the pre-occlusion abduction.

In 28 cases the two were equal, and in 76 or 25 per cent., the former exceeded the latter, sometimes very greatly, the most extreme case showing abduction 13° before and exophoria 30° at the end of the test, the abduction becoming 31° .

It becomes evident that although the post-occlusion exophoria is more commonly less than the pre-occlusion abduction, exceptions to this rule are sufficiently frequent (25 per cent.) to make any dependence upon this relation quite unreliable.

The great variability in the relation between abduction and exophoria is worthy of emphasis. Thus in 36 cases

in which the post-occlusion test showed an exophoria of 2° the pre-occlusion abduction varied from 1° to 14° . In

TABLE 14.

Relation of exophoria after test, to abduction before test.

ABDUCTION BEFORE	EXOPHORIA AFTER																		
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	30°
19°																			
18°																			19°
17°																			
16°																			19°
15°																			
14°	1	1																	
13°	1																		30°
12°																			
11°																			
10°	3	2	4	6	1	1	7	2	4	1	2	2							
9°	1	5	1	3	4	5	2	3	3	2	2								
8°	8	10	5	7	7	7	5	3	5	4	1	2							
7°	2	3	9	7	6	5	2	4		4	2								
6°	2	6	7	3	4	7	5	2	1	1	1	1							
5°		4	5	1	3	2			1										
4°	3	1	2	2	2	2		3		2	2								
3°		2	1			1	1												
2°		1	1	1															
1°		1																	

19 cases in which the post-occlusion exophoria measured 10° the pre-occlusion abduction varied from 2° to 12° .

On the other hand, of 61 cases in which the abduction was 8° before the test, the exophoria after it varied from 1° to 12° , and in 19 cases showing pre-occlusion abduc-

tion of 4° , the post-occlusion exophoria varied from 1° to 11° .

The truth is that there is no relation between the pre-occlusion abduction and the post-occlusion exophoria except that in 75 per cent. of the cases the total exophoria does not exceed the primary abduction, if the doubling point be taken as the measure of abduction.

CHAPTER IX.

INDICATIONS FOR THE USE OF THE TEST.

IN a broad sense, if any inference can be drawn from the observations here detailed, the test is indicated whenever it is desirable to obtain the greatest knowledge possible of the position of rest, but in a narrower sense there are certain definite groups of cases in which it is specially indicated, and some in which no progress is made, or any solution arrived at without it.

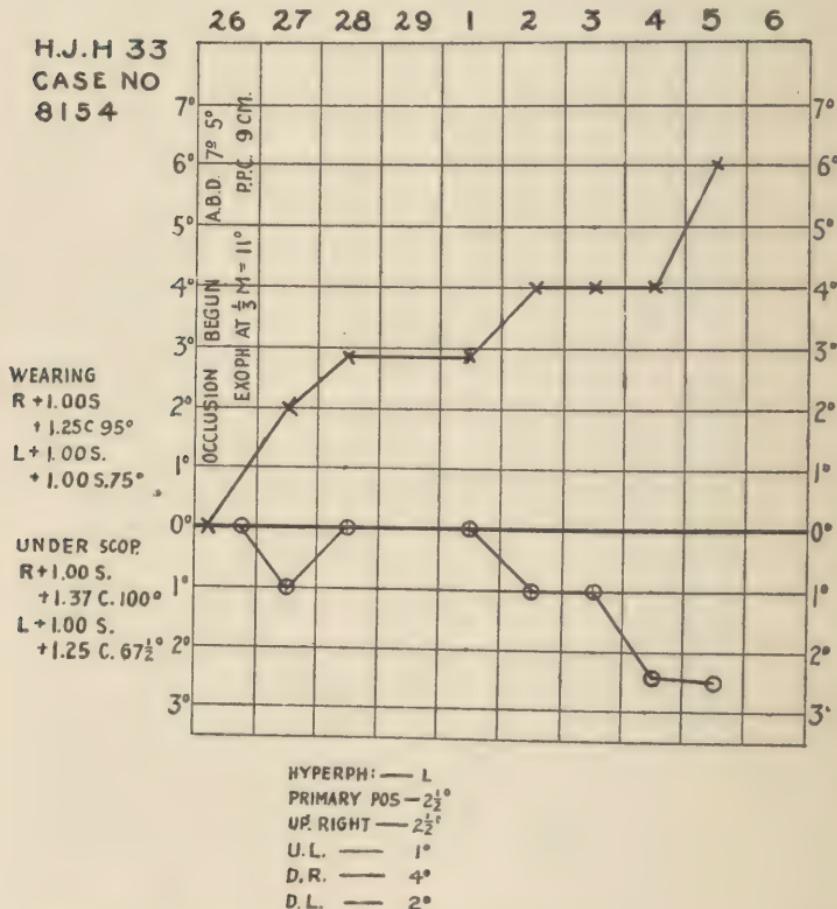
In the first place there is the very definite group of cases in which the symptoms are aggravated by an apparently accurate correction of the refractive error, especially astigmatism. Long ago the writer formulated for himself the rule that, when a correction of refractive error makes the symptoms worse, a latent muscle error is present. The explanation presumably is that the formation of better defined images on the retina necessitates more exact binocular fusion and so a greater demand is made on the extrinsic muscles. The same principle no doubt is the explanation of the photophobia, sometimes intense, to which heterophoria gives rise. The brighter the light, the more clearly defined is the retinal image, partly on account of the smaller pupil and partly because the accommodation is stimulated to greater effort, and so an increased muscular effort has to be made to accomplish accurate fusion.

Some of the worst cases of photophobia seen, have been due to latent faults in the muscle balance, and relief has followed their correction after detection by the occlusion test.

Many patients give the history of having consulted one or more ophthalmologists of repute, being prescribed for, and of finally leaving the glasses off because they found themselves more comfortable without them.

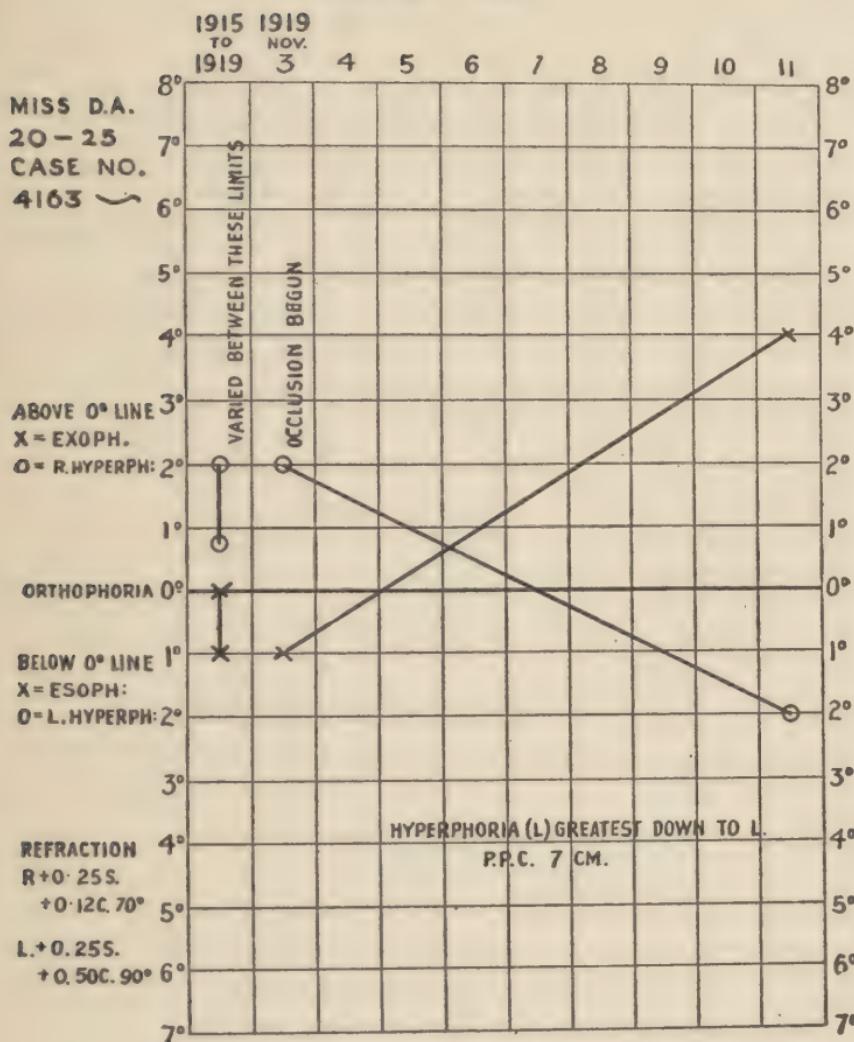
CHART VII.

FEB. 1920



Some wear their glasses with comfort for a time, then leave them off "to rest their eyes" from discomfort presumably due to muscle strain, and after a while have to

CHART VIII.



replace them to relieve discomfort of some other type, presumably due to accommodative strain, so that the complaint is sometimes heard that since beginning to wear glasses, they are comfortable neither with nor without them.

Chart VII shows in a graphic way the effect of the occlusion test in a case of this type. On account of severe and constant sense of strain this patient had consulted 10 to 12 ophthalmologists of national reputation in different parts of the country with invariable failure to obtain relief. His refraction, carefully measured, under cycloplegia, was found to be corrected with essential accuracy by the glasses he was wearing. The pre-occlusion test showed orthophoria, the final after eight days' occlusion, exophoria 6° and L. hyperphoria $2\frac{1}{2}^{\circ}$. A prismatic partial correction of the error gave him a high degree of relief.

In another group the correction of the refractive error does not aggravate the symptoms, neither does it relieve them. In this group the indication for the use of the test is not so strong as in the first, nevertheless, if the symptoms are indubitably those of eye-strain, and cannot be accounted for by any other local condition or by any general disorder, occlusion will furnish an explanation in a great many cases.

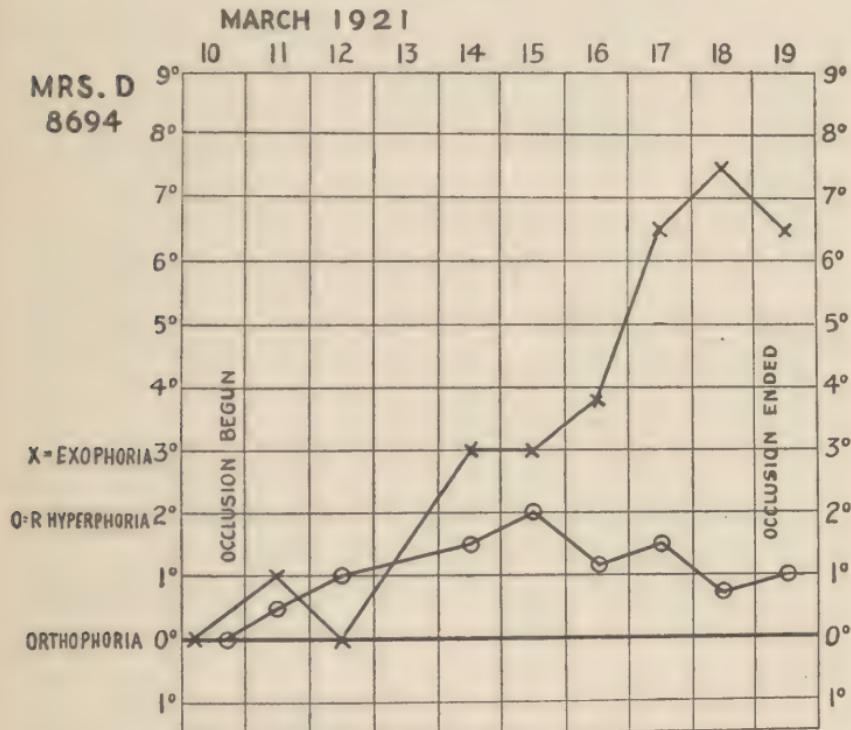
In still another group in which the presence of some fault in the muscle balance can be detected in the ordinary way but its correction with that of the refraction fails to give the desired relief, an occlusion test will often show a much higher degree of error, or an error of a different kind; for instance the hyperphoria may change from R. to L. Chart VIII illustrates a case of this type.

Although strictly monocular pain is rarely due to heterophoria there are exceptions to the rule, and it is therefore worth while, in cases in which there is no other evident

cause, to ascertain more definitely the state of the muscle balance.

Thus, Mrs. D. had suffered for many months from constant pain in and around the right eye. A full cor-

CHART IX.



rection of her hypermetropia and astigmatism gave no relief whatever; muscle tests showed functional orthophoria. Finally an occlusion test being suggested and accepted, the result was as shown in Chart IX, the development of 7° of exophoria and R. hyperphoria 1° . On the third day of occlusion the pain ceased entirely, and did not return.

Patients are frequently referred to the ophthalmologist by the general practitioner on the ground that some form

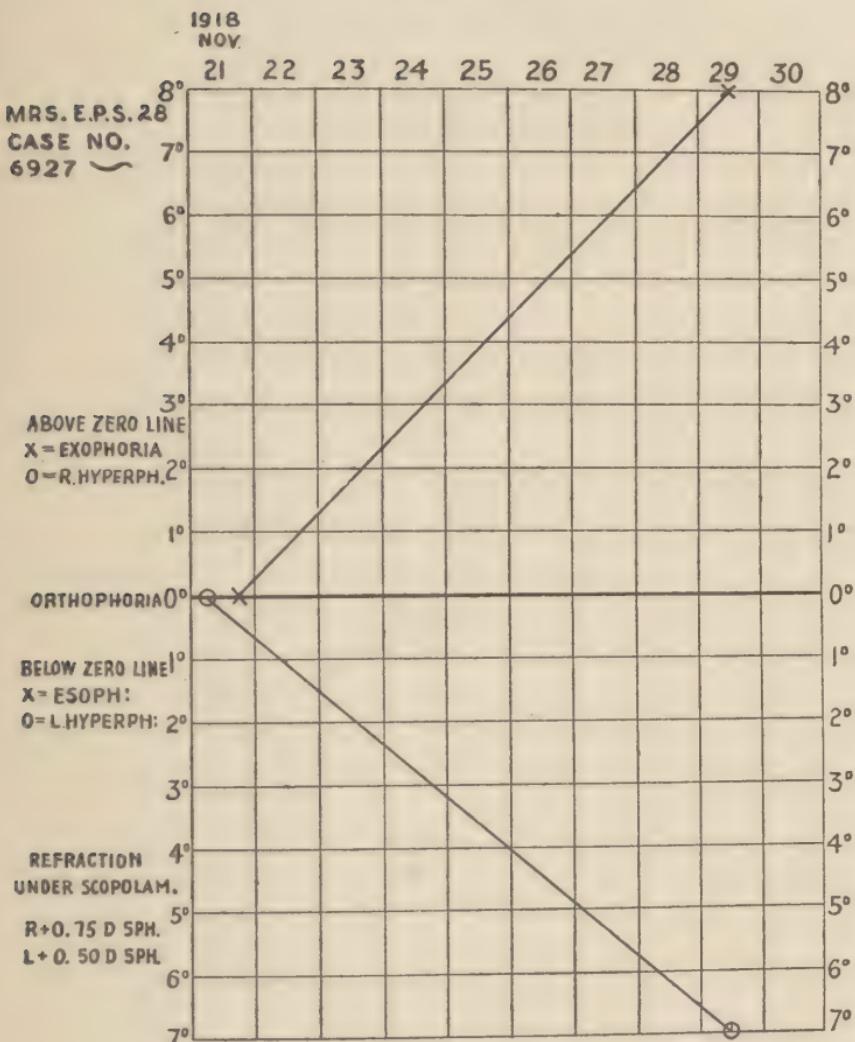
of eye-strain may be responsible for symptoms of a neurasthenic type, which do not yield to the correction or treatment of such non-ocular errors as can be demonstrated. A final judgment cannot be arrived at in these cases without as complete a test of the muscle balance, as of the refraction and accommodation.

A very summary examination of the statistics given above will show that the ordinary short methods of investigation may completely fail to reveal errors of the highest importance, or may be misleading as to their character.

Mrs. S., aged 28, Chart X, was referred by her physician because he thought that every possible cause of her neurasthenic symptoms had been eliminated with the exception of eye-strain. Examination of her eyes revealed practically no error. Under cycloplegia the R. eye accepted + 0.75 sph., and the left + 0.50 S. Tests of the muscle balance showed orthophoria. Before giving a final opinion, however, an occlusion test was decided upon. At the end of a week's occlusion the test showed exophoria 8° and L. hyperphoria 7°. The patient volunteered the statement that the week of occlusion was the most comfortable she had ever had.

The use of the method is also indicated by those not very uncommon cases in which patients after prolonged trial will not accept a full correction of hypermetropia after cycloplegia. Blurring of distant objects persists in spite of the constant wearing of the glasses for a long period. This persistent accommodative spasm is associated in some cases with overaction of the extrinsic muscles in the interests of fusion. This is simply the converse of what occurs in the production of convergent squint or convergence excess in hypermetropia. Here the effort to accommodate causes excessive convergence, *i.e.*, converg-

CHART X.



ence is subordinated to accommodation in the interest of clear vision. In the cases just referred to of accommodative spasm, accommodation is subordinated to fusion in the interest of single vision, and blurring in the distance results.

In any particular case the result seems to depend upon which of the two centers is the more active, the center for accommodation, or the center for fusion. Or to put it in another way the relative accommodation (or convergence) is insufficient or not elastic enough to permit the accommodation to adjust itself to the muscle balance so as to permit clear as well as single vision, and the more powerful center dominates the weaker. If the center for accommodation is the stronger we have clear vision and excess of convergence, latent or manifest; if the fusion center is the stronger we have single vision, but blurring in the distance. A case of this kind which was very instructive to me is published in the May, 1922, number of the Archives of Ophthalmology.

Many years ago the great frequency with which the presence of astigmatism, anisometropia and heterophoria were observed in cases of myopia—it is possible to go further than that and say that the fact that cases of myopia were practically never seen without one or more of these conditions being present—necessarily suggested that they might be important factors in its development and progress. The above statistics indicate that the assumption that an ordinary short test of the muscle balance reveals the truth is not justified and consequently when myopia progresses in spite of accurate correction of the astigmatism and anisometropia as far as practicable, and the adoption of such hygienic measures as are indicated, an occlusion test may reveal the presence of a latent deviation. It is as-

sumed that the presence of a latent deviation necessarily causes increased tension of the extrinsic muscles and therefore increased compression of the globe.

The use of the method is also particularly indicated in cases selected for operative treatment, it being then extremely important to know as accurately as possible the kind and degree of error, to determine the amount of operative correction. It is also indicated after healing has taken place, for the degree of correction cannot be determined with any certainty without it.

CHAPTER X.

EFFECT OF OCCLUSION ON SYMPTOMS.

THE effect of occlusion upon the symptoms varies in different individuals and its nature cannot always be regarded as a reliable indication of the future effect of treatment based upon its findings, though it must be admitted that it is extremely suggestive. In many cases the patients experience an immediate amelioration or even a complete cessation of their symptoms during the occlusion period, and it is reasonable in such cases to expect a satisfactory result when the error is corrected. But it must not be forgotten that occlusion completely annuls all binocular strain, and that it is rare indeed when any correction, prismatic or operative, can do the same thing. There are many patients who are more comfortable with one eye occluded than under any other conditions, and this may be true when no fault in the muscle balance can be found at the end of occlusion. Thus, a young man, the subject of severe asthenopia, preventing him from doing any reading, in spite of a very careful correction of his refraction, found himself able to read indefinitely during the occlusion period. At the end of this period, however, tests showed perfect orthophoria, as previous to the occlusion. The binocular function was evidently at fault, but the fault could not be detected, perhaps because a week's occlusion was too short a period to effect a relaxation of his muscles. The symptoms returned on the use of both eyes being resumed.

Many patients, however, tolerate occlusion with great difficulty. The headaches and other symptoms may con-

tinue unchanged, more or less vertigo, nausea and even vomiting may be superadded, though such symptoms are rare, and apparently psychic in origin, due to the nervousness and impaired orientation associated with the loss of binocular vision and often to the glare of the ground glass. These and other annoyances are greatly diminished by using a black patch instead of a ground glass, or pasting a piece of black paper over the back of the latter.

The occurrence of such unfavorable symptoms during the test need not necessarily be interpreted as of bad omen, as some of these at least are followed by a finally satisfactory result.

CHAPTER XI.

NEAR POINT OF CONVERGENCE.

THE near point of convergence is practically unaffected by the test. Thus, in two only of 82 cases in which the p.p.c. was taken before and after was there more than 2 cm. increase. In 30 cases there was no change, and in 22 the distance was shortened. In fact such variations as occurred were within the normal limits of variation on different days.

TABLE 15.

Exophoria at $\frac{1}{3}$ M and near point of convergence before occlusion. 117 cases.

		19°	18°	17°	16°	15°	14°	13°	12°	11°	10°	9°	8°	7°	6°	5°	4°	3°	2°	1°	
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	CM. NEAR POINT OF CONVERGENCE	
EXOPHORIA AT $\frac{1}{3}$ M																					
		2		1																	
		2		1																	
ORTHOPHORIA																					
ESOPHORIA AT $\frac{1}{3}$ M																					
		1	3	4	1																
		2																			

Table 15 shows that a convergence insufficiency (7 cm. from the base line being accepted as the arbitrary standard) may exist either with an actual pre-occlusion esophoria at the near point or with orthophoria, or with (82)

any degree of exophoria, and on the other hand that a normal p.p.c. may co-exist with any degree of exophoria at the near point. Thus, the table shows 23 cases in which the p.p.c. was 7 cm. from the base line or less with a near point exophoria of from 7° to 17° , and other cases in which a low near point exophoria was associated with a too distant p.p.c., thus one case of near point exophoria 3° and p.p.c. 21 cm.

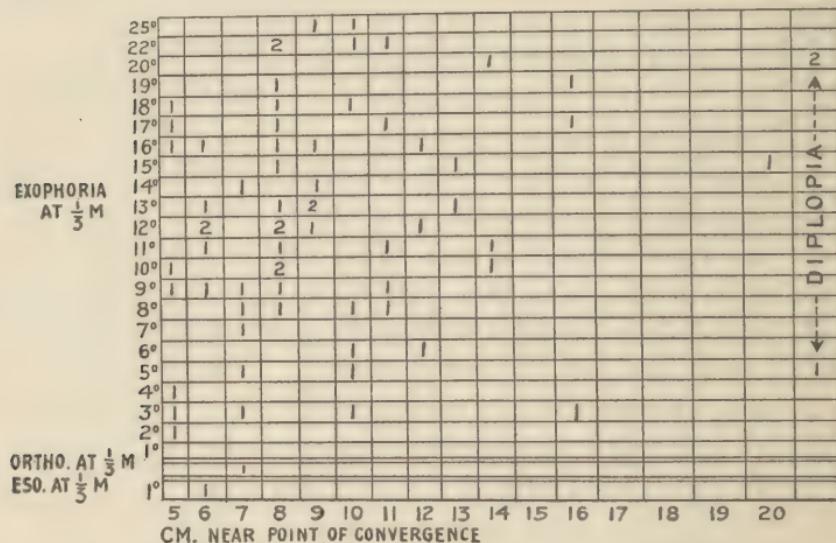
In view of these facts, can the near point of convergence alone be considered as evidence for or against convergence insufficiency? Apparently not, except in extreme or well marked cases, and the fact that many people who have a normal p.p.c. suffer from asthenopia in spite of correction of all error, raises the question as to whether the measure of the momentary maximum convergence effort has so much importance as usually attributed to it, and whether the question of endurance, a factor not so easily determined and probably often depending on conditions not localized in the eyes, is not of greater importance.

Table 16, in which the post-occlusion near point exophoria is shown with the p.p.c., emphasizes still more strongly the absence of any constant relation between them, many of the highest degrees of exophoria being associated with normal or supernormal convergence.

But it may be well at this point to emphasize the fact that many patients have a near point of convergence far more distant than the arbitrary standard, who appear to suffer no inconvenience from it and the question arises whether an exaggerated importance has not been given to the distance of the p.p.c., or whether the standard fixed is not too arbitrary, in other words whether what may constitute a good working p.p.c. may not differ very materially in different individuals.

TABLE 16.

Exophoria at $\frac{1}{3}$ M and near point of convergence after occlusion. 70 cases.



The cases seem to group themselves into four classes—

(1) Cases of marked near point exophoria with normal convergence.

(2) Cases of marked near point exophoria with subnormal convergence.

(3) Cases in which there is practically no near point imbalance but the convergence is subnormal.

(4) Cases in which there is practically no near point imbalance and the convergence is normal.

Symptoms may arise in Classes (1), (2) and (3).

In Class (1)—because the load is too great.

In Class (2)—because the load is too great and the convergence too weak.

In Class (3)—because the convergence is unequal to a normal demand.

CHAPTER XII.

TREATMENT.

ALTHOUGH the chief object of this essay has been to show the influence of prolonged occlusion in determining the position of rest, in other words in making a more accurate diagnosis, it seems desirable to comment with more precision on the methods of dealing with the conditions found.

The general condition of health of the patient, including the reserve of nervous energy with which he was endowed at birth, has a large influence beyond any doubt in determining whether a given form or degree of muscle imbalance will give rise to symptoms or not. A great many people are the subjects of faults of this nature without giving any symptomatic evidence whatever of their presence. On the other hand symptoms of very marked character arise in patients of the neurotic type or of a low state of general health, from errors of very low degree, and it is consequently advisable to correct such errors in the presence of otherwise unexplained symptoms.

It may be noted, moreover, that in most of these cases resort is had to the ophthalmologist because of the previous failure of general treatment to afford relief.

Assuming that questions of the bearing of general health upon the symptoms have been settled, the question of the treatment of local ocular conditions is next in order.

No doubt the refraction should be accurately corrected, but exception must be taken to the common statement that such correction has a sedative effect upon the muscle condition or symptoms. This may be true of some cases of

esophoria associated with hyperphoria, *i.e.*, cases of pseudo-esophoria, but the effect of refractive correction in many cases of latent exophoria and hyperphoria is to make the symptoms worse, for reasons already stated.

Aggravation of symptoms following correction of the refraction is in itself strong presumptive evidence of the existence of a latent heterophoria, and relief must be sought, not in modification of the refractive correction, but in an intensive examination and analysis of the oculomotor system, and especially in the determination of the relative or anatomical position of rest.

If the presence of a muscle imbalance has been determined, the decision has to be made between the three well-recognized methods of treatment.

- (1) Exercises—prism or other.
- (2) The constant wearing of prisms to permit the visual lines to fall into or approximate their anatomical position of rest.
- (3) Operative treatment.

The following observations and suggestions are made purely on the basis of the writer's own experience, and their value is limited accordingly.

First as regards exercises. In spite of the widespread use of various methods with the underlying principle of strengthening the supposedly weak muscles or stimulating the nerve centers, very few well-authenticated cases of improvement by this method in the hands of others have come under my observation, and in these few the benefit has usually been temporary only. In my own practice benefit has been still more exceptional though not entirely absent. Even in cases of convergence insufficiency, which would seem to be especially suitable for this method, any material improvement has been rare, though cases have

occurred in which satisfactory improvement both in the p.p.c. and symptoms have resulted. When I prescribe exercises now, it is less with the expectation of benefit than for the purpose of determining by actual trial its futility in the particular case in point, and leaving the field open for the adoption of some other more promising method of treatment.

My experience in the prescription of prisms for constant wear has been far more satisfactory, extending over a long period of years, during which the series of 700 consecutive cases upon which this essay is based constitutes only a fraction of the total number of cases observed. This experience leads to the following suggestions:

That in low degrees of exophoria, *i.e.*, up to 4° or 5° , the greater part or all the error found after occlusion can often be corrected with advantage. I have ceased to consider some of the lower degrees as of no importance. The prismatic correction of even 3° has been followed by surprisingly good results.

Thus, Mrs. H. E. M., age 43, suffering from extreme nervousness, severe headaches accompanied by nausea and vomiting, apparently related to the use of her eyes, never having been able to get satisfactory glasses, was subjected to the test for 7 days. At the end of this period she showed R. hyp. $\frac{3}{8}^{\circ}$, Ex. 3° . Under cycloplegia each eye accepted + 0.50 sph. She was ordered:

R: + 0.25 S. \bigcirc $1\frac{3}{4}^{\circ}$ prism base down — 155°
L: + 0.25 S. \bigcirc $\frac{3}{4}^{\circ}$ " " in

She returned four years later, having become presbyopic in the interval and in reply to a question as to what the effect of the glasses amounted to, said: "What you did for me then completely relieved me of my symptoms."

The higher the degree of error the smaller is the proportion of it that can be corrected, but many cases of 8° , 10° or 12° get great benefit by the correction of a half or two-thirds of the error. It is rare when prisms stronger than 4° on each eye can be worn with benefit for the reasons previously stated. There are exceptions to the rule, however. Thus, a patient consulted me a few years ago wearing a 9° prism over each eye prescribed by the late Dr. Alleman, formerly of Brooklyn, three years previously. With these glasses she had had satisfactory relief from her symptoms. These prisms were re-ordered with a change in her refractive correction, relief again resulting.

The degree of prismatic correction which can be worn with advantage varies in different patients, a variation of half a degree sometimes making all the difference between comfort and discomfort, and some patients do not tolerate prisms at all. No doubt a large psychic element is here present.

My experience in the prescription of prisms in esophoria is naturally much smaller than in exophoria, and it is only when the evidence shows that the case is one of esophoria and not pseudo-esophoria that I prescribe them at all.

In hyperphoria the use of prisms for constant wear is generally conceded to be of high value though the prescription of them has to be tentative as to the degree of correction. The very irregular distribution of the error over the field of fixation explains the lack of uniformity in the results. As a general rule, the error found in the primary position can be taken as a guide to the amount of correction, all or the greater part being corrected, but this rule must be modified in cases in which great differences in the degree of error are present in different parts of the field. The relative deorsumduction and sursumduction may be used as a control. The careful measurement of

these ductions both before and after occlusion is, indeed, often of great value in determining the character of the prescription.

After all it must be conceded that the prescription of prisms has to be done in a tentative manner. The length of time it takes for patients to get used to the new relation between accommodation and convergence varies with different people, and failure often results because the necessary length of time is not devoted to the attempt.

In the field of operative treatment my experience is not great enough to attempt any but tentative generalizations, but I am satisfied that the degree of error which it should be the aim to correct, or materially diminish, is that which is found at the post-occlusion test.

In cases of exophoria due to pure divergence excess that tenotomies of the externi should be done.

In cases of exophoria in which the near point of convergence is too distant and cannot be brought near the normal by exercise, advancement of the interni would be the operation of election.

Having abandoned the idea that lateral deviations depend upon the vertical, at any rate at all commonly, I am consequently under no intellectual compunction to correct the vertical previous to attacking the lateral deviation. In fact the operative correction of the lateral deviation has been followed in some cases by a marked diminution in the hyperphoria (see Chart II).

APPENDIX.

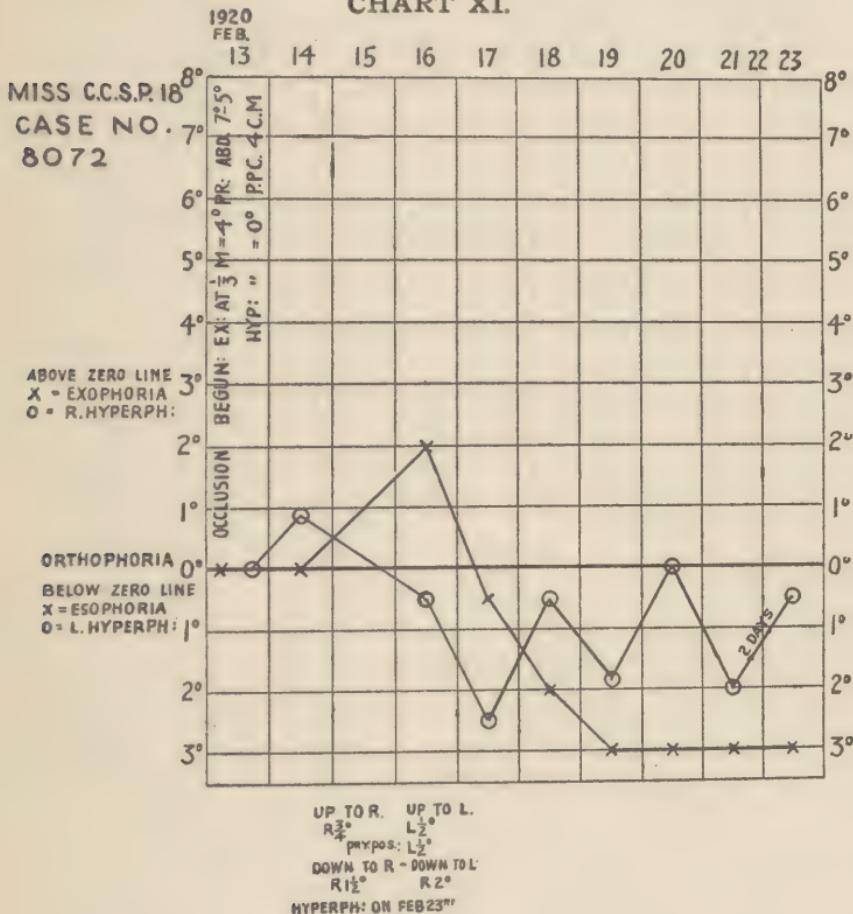
In the 7th Edition of Fuchs, the translator expresses the opinion that such Prolonged Occlusion "tends to make the eyes revert to their infantile state in which, not being controlled by co-ordinative influence, they exhibit a varying imbalance."

In spite of the keen appreciation on the part of the writer of the very high value of Dr. Duane's opinion on any muscle problem, he cannot refrain from making the following observations.

First: That the P. O. Test is simply an extension in point of time of the screen and parallax test of which Dr. Duane himself has been the most strenuous and eminent advocate. It is evident from the above quotation that there is a point at which he thinks this test becomes unreliable. Applied for a short time (how short ?) it is reliable; applied for a longer period (how much longer ?) it is unreliable. I am unable to find in the numerous cases I have examined any adequate reasons for the acceptance of this position. Although in many cases the development of the error does not show a steady and uniform curve, the general trend is in the same direction, the variations from day to day are usually slight, and explainable by assuming an occasional partial resumption of the old habitual spasm during the process of gradual relaxation. In the presence of brain tumors, and presumably other organic brain changes, great variations may be present, of which the case shown in Chart XI is a good example.

Miss C. S. P., age 18, first seen on Jan. 7, 1920, when she complained of severe headache, aching of eyes, and stomach disturbance since reading a magazine story in Christmas vacation. Had never worn glasses.

CHART XI.



Refraction under scopolamine

$$\text{R.} + 2.50 \text{ S} + 0.37 \text{ C ax } 115^\circ \frac{6}{6} +$$

$$\text{L.} + 2.50 \text{ S} + 0.25 \text{ C ax } 70^\circ \frac{6}{6} +$$

Oph. o.d.s. somewhat blurred, vessels best seen with
+ 3.00 D.

Glasses (full correction —0.50 sph.) made her comfortable for two weeks. After that she had headache on using eyes and was in bed off and on for two weeks.

A ten day Prolonged Occlusion test was then made, during which she had a very severe headache.

On Feb. 23d, oph. showed definite papilloœdema, the vessels being clearest with +7.00 or +8.00 D. sph.

She developed other symptoms of cerebellar tumor, which upon surgical exploration it was found impossible to remove, and died a few months later.

As a rule there is a fairly uniform and gradual development of the error until the degree remains about the same from day to day, and there is no point at which it seems proper to say that up to this point the test shows the real facts, and beyond this point is misleading.

Moreover, in cases of blindness of one eye, in which the test is therefore carried to its ultimate limit, the deviation which develops is not a variable one, and Bielschowsky and others have assumed that it represents the relative position of rest.

Second: The infantile state is naturally that state out of which functional orthophoria, or rather binocular vision, has developed, and if it be conceded that the Prolonged Occlusion Test tends to permit a reversion to it, should not this be regarded as evidence that this infantile state has persisted, and is also an adult state, obscured only by the instinct or reflex of binocular fusion? With the removal of all attempts at fusion an approximation to the condition antedating binocular vision is to be expected, and is not a knowledge of it necessary to the understanding of the problem which the muscle balance includes? Do we, as a matter of fact, know much about the muscle balance in infancy and the development of binocular vision? While it is true that the eyes of some infants show occasional

deviation, chiefly in, sometimes out, the eyes of the majority appear to be straight, and to remain so, and is it not just as likely that the occasional deviations above referred to indicate the true position of rest, as that they show a "varying imbalance"?

If it be true that the Prolonged Occlusion Test does develop a reversion to the infantile state, then it gives us very surely important information as to what that condition is or was, and the 700 cases here recorded show how greatly this state varies in different individuals, and out of what varying conditions functional orthophoria or binocular single vision has to be developed, and it is not surprising that the muscle work and expenditure of nerve energy required to accomplish and maintain the function at the necessary and habitual point of perfection should give rise, at any rate in those whose endowment in nerve energy is not up to the average, to symptoms of one kind or another, practically to symptoms of nervous exhaustion.

Third: The chief proof of the reliability in the main of the observations made by this test consists in the fact that the results of treatment based upon them have proved in a large number of cases to be far more satisfactory than those previously obtained, and that the facts thus discovered prove to be the key to the solution of the problem. Many of the cases included in this series have been under my observation many years, without obtaining satisfactory relief until after the P. O. Test showed the presence of errors previously undetected; and many others had passed through the hands of ophthalmologists of national reputation with a similar result. In fact all these 700 patients were examples of failure in greater or less degree to obtain relief by full correction of the refraction and such muscle errors as were demonstrable by the usual tests.

Is it true that binocular fusion is acquired only by experience (the empiristic theory) or that it is an inherent function due to anatomical conditions, the presence of the fovea, in which alone a keen sense of form resides, and inborn physiological processes (the atavistic theory)?

A case came under my observation some years ago which strongly supports the latter theory.

A young man, age 18 years, had been the subject of convergent alternating strabismus at 3 weeks after birth, and at 15 months both interni were cut. At 18 years his eyes were divergent, and the right deviated upwards. It is exceedingly unlikely that this patient had ever had the opportunity of acquiring binocular fusion by experience. The right superior rectus was partly divided and at a later date the R. int. was advanced with a single stitch. The next day the patient announced that he could use the two eyes together and examination showed this to be the case.

The writer referred to the use of this method in a paper on "Obscure Cases of Eye Strain," published in the N. Y. Medical Journal in Sept., 1893, and published a preliminary note on the subject entitled "A Note on the Use and Non-use of the Occlusive Bandage in Cases of Heterophoria," in the Ophthalmic Record of March, 1897, and also the following papers:

"The Determination of the Relative Position of Rest, by Prolonged Occlusion of One Eye," N. Y. State Journal of Medicine, April 28, 1915.

"The Detection and Measurement of Latent Ocular Deviations. The Inadequacy of the Ordinary Methods Used." N. Y. Medical Journal, November, 1918.

"The Influence of Prolonged Monocular Occlusion in Revealing Errors of the Muscle Balance." British Journal of Ophthalmology, April, 1920.

"Prolonged Monocular Occlusion as a Test for the Muscle Balance." Trans. Am. Oph. Soc., 1920.

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